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EDITED BY J. McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

MAY, 1936

THE EVOLUTION OF PHYSICAL CONCEPTS

By Dr. SAUL DUSHMAN
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The content of physics, as well as of all the other branches of science, has changed radically since the beginning of the century. No one realizes this more acutely than those of us who, like the writer, began our scientific training three decades or so ago. I still treasure a copy of Atkinson's translation of Ganot's Physics. It is dated 1893, although I purchased it second-hand seven years later. As I glance over its 1,100 odd pages and compare the contents with a college text of the present day, I note with consternation that my undergraduate course in physics was sadly deficient. It contained very little or absolutely no mention whatever of most of the topics which are as familiar as the alphabet to the average student of physics in 1936.

Let us summarize briefly the new developments in physical science since 1895.

Roentgen discovered x-rays in that year, and Becquerel made his first observations on radioactivity in 1896. In 1902–1903, Rutherford and Soddy brought forward their theory of spontaneous disintegration of radioactive elements. The atom had lost its attributes of indestructibility. In 1897 J. J. Thomson first published the results of his investigations on the charge and mass of the electron, and shortly afterwards O. W. Richardson began his researches on thermionic emission, thus initiating an era which was to witness the harnessing of these electrons to the electromagnetic radiations which had been discovered by Hertz in 1887.

During the last decade of the nineteenth century refined measurements were carried out on the energy distribution in the radiation from a black body. These observations could not be reconciled with certain deductions from the kinetic theory of gases and statistical mechanics. In consequence, Planck was led in 1901 to enunciate his theory of energy quanta. The new suggestion received scant attention in spite of its application by Einstein (1905) to the interpretation of the variation with temperature of the specific heats of solids.

But in 1911 Rutherford put forward his theory of the nuclear atom; in 1912 v. Laue carried out his famous demonstration of the wave-nature of x-rays, and in 1913 Moseley published his investigations on the relation between x-ray frequencies and nuclear charge. All these observations and the mass of spectroscopic data, which had hitherto failed to find a satisfactory explanation, were now fused together into a beautiful conception by N. Bohr in 1913.

It is difficult for the present generation to realize the immense transformation in physical concepts which resulted from the publication of Bohr's papers. The idea of discrete energy states as the origin of spectral lines furnished a union of Planck's quantum concept and elec-

tromagnetic radiation. However, this new point of view raised what appeared to be insurmountable difficulties. Bohr used classical, that is, Newtonian mechanics to give us a model of an atom constituted of one or more electrons revolving in periodic orbits about the nucleus. But in order to limit the number of these orbits, as required by the observations on the relations between spectral lines, he had to bring in a so-called quantizing condition. Only those orbits can exist, he claimed, for which the angular momentum of the electron is an integral multiple of $h/2\pi$. The theory worked for hydrogen and ionized helium, but it required a tremendous amount of patching to explain the spectral behavior of more complex atoms. Bohr attempted to bridge the gap between his peculiar mechanics and Newtonian mechanics by means of his famous Correspondence Principle. But none of the mathematical physicists could even suggest a plausible theory for the behavior of the electrons in a helium atom.

Moreover physicists were confronted with another grave difficulty. Is light, or electromagnetic radiation in general, to be interpreted on the basis of the undulatory or on that of the corpuscular theory? The experiments of A. H. Compton in 1923 showed conclusively that in the interaction of x-rays with electrons the radiation behaves as if constituted of corpuscles having energy $h\nu$ and momentum $h\nu/c = h/\lambda$. On the other hand, these x-rays may be diffracted by a crystal lattice and they then behave as waves.

Physicists were thus confronted with a dualistic conception of the nature of radiation. But meantime the difficulties involved in the Bohr theory began to accumulate in spite of the valiant efforts of Sommerfeld and a number of theoretical physicists. In 1925 Goudsmit and Uhlenbeck showed that the electron must be regarded as possessing an energy of spin. This smoothed over some of the difficulties, but raised others. There arose a searching of the heart, as it were, which was reminiscent of that time five hundred years or so ago when the Ptolemaic system began to break up under its own weight of *ad hoc* assumptions. A French physicist, Louis de Broglie, boldly suggested (1925) that perhaps, after all, classical mechanics is not valid for atomic systems, that corpuscles which possess a momentum of the order of magnitude of h may not behave like Newtonian particles at all and that they may even exhibit the properties of waves. Thereupon an event occurred which was quite dramatic. Two American physicists, Davisson and Germer, showed that de Broglie's hypothesis was the very explanation which could account for their observations on the reflection of electrons from nickel crystals. Moreover, to add further evidence in confirmation of de Broglie's suggestion, G. P. Thomson repeated with electrons the same experiment which v. Laue had devised to demonstrate the wave nature of x-rays. Only in this case, what was proven, beyond the shadow of a doubt, was that if G. P. Thomson's father had not already found that the electron behaves like a little bullet, the son would have concluded from his experiments that the electron is a wave motion.

The physicists, like other intelligent human beings, have always had the intuitive feeling that any interpretation of nature must be monistic. It made them extremely uncomfortable, especially before their colleagues in the realm of philosophy, to be espousing waves on Mondays, Wednesdays and Fridays, as Einstein described it, and to think in terms of corpuscles on intervening days. Perhaps they needed a day of rest in order to reconcile this Jekyll and Hyde existence.

In this dilemma the physicists began to inquire, quite rightly, "What got us into this trouble?" Well, for one thing, we had tried to put into our theories more than we could ever test by observation.

It became evident that the Bohr model was too concrete. It suggested too many questions that could not be answered. Bridgman designates them "meaningless questions." Perhaps that is why we discard so readily the naïve stories of our childhood. The fairies and princes are so well drawn that when we begin to compare them with actual beings it is no longer possible to believe that both can exist in the same world.

Here we must abandon for a moment our historical order and go back to the period 1905–1915 in which Einstein formulated first his special theory, and then the general theory of relativity. To the layman Einstein's logic represents an "esoteric mass of abstract formulas" and a great deal of mysterious discussion of a fourth dimensional world. But for the physicist the greatest service rendered by the theory of relativity was this,—that it removed completely from scientific thought those arbitrary elements which Newtonian mechanics had transmitted to us, *viz.*, absolute time and space. At one swoop, the ether, that noun for the verb to undulate, was shown to be a completely unessential concept; and in place of the Newtonian concepts new ones were introduced by which mass, time and distance could be defined in such a manner as to be independent of the particular conditions of the observations.

No one has pointed out more clearly than has Bridgman in "The Logic of Modern Physics" Einstein's contribution in changing our attitude towards physical concepts. "It is a task," he writes, "for experiment to discover whether concepts defined in a certain manner correspond to anything in nature. . . . In general, we mean by any concept nothing more than a set of operations; *the concept is synonymous with the corresponding set of operations.*"

> It is evident [he writes] that if we adopt this point of view toward concepts, namely that the proper definition of a concept is not in terms of its properties but in terms of actual operations, we need run no danger of having to revise our attitude toward nature. For if experience is always described in terms of experience, there must always be correspondence between experience and our description of it, and we need never be embarrassed, as we were in attempting to find in nature the prototype of Newton's absolute time. Furthermore, if we remember that the operations to which a physical concept are equivalent are actual physical operations, the concepts can be defined only in the range of actual experiment, and are undefined and meaningless in regions as yet untouched by experiment. It follows that strictly speaking we can not make statements at all about regions as yet untouched, and that when we do make such statements, as we inevitably shall, we are making a conventionalized extrapolation, of the looseness of which we must be fully conscious, and the justification of which is in the experiment of the future.

Bridgman wrote these passages in 1925–6 and the ideas which he expressed were agitating other minds as well. The difficulties inherent in the Bohr theory and in the dualistic theories of the nature of matter and radiation were apparently insurmountable. "Where do we go from here?" was the question uppermost in the minds of the leaders.

The answer, first perceived most clearly by Heisenberg and Bohr, is that this dualism is actually inherent in the experimental arrangements used, in the agencies of observation themselves. *The nature of the experiment controls the result actually observed.* The difficulty is, that we have always assumed that we could treat phenomena as something apart from the tools used in the observations.

When we measure a length with a meter stick, or observe the position of an oil drop through a telescope, we are justified in assuming that the act of observing has introduced no effects on the object of observation. Consequently, it is possible, in ordinary dynamical problems, to specify the instantaneous state of a particle in terms of its position (which we shall designate by x), and its velocity, v, or more accurately, its momentum, $p = \mu v$. From a knowledge of the forces

acting on the particle, it is then possible to predict its subsequent behavior, as, for instance, its position and velocity after any period of time, t. Such a prediction is valid because it is possible to make observations on the initial conditions without "spoiling" the results of the measurements.

> However [as Heisenberg has pointed out] this assumption is not permissible in atomic physics; the interaction between observer and object causes uncontrollable and large changes in the system being observed, because of the discontinuous changes characteristic of atomic processes. The immediate consequence of this circumstance is that in general every experiment performed to determine some numerical quantity renders the knowledge of others illusory, since the uncontrollable perturbation of the observed system alters the values of previously determined quantities. If this perturbation be followed in its quantitative details, it appears that in many cases it is impossible to obtain exact determination of the simultaneous values of two variables, but rather that there is a lower limit to the accuracy with which they can be known.

For instance, in the Bohr theory of the hydrogen atom, the motion of an electron is assumed to resemble that of the earth around the sun. It is assumed that we can measure both the position and velocity of the electron at any instant and that from this we can derive a magnitude which we designate as frequency of revolution in an orbit. But is it possible to specify position and velocity simultaneously for an electron in an atomic system? Heisenberg's answer is that it is impossible to do this. In fact, the more accurately we attempt to determine the position, the less accuracy we attain in the measurement of velocity, and *vice versa.* If we designate the uncertainty in the determination of momentum by Δp, and that in the determination of position by Δx, then it may be shown that there exists a relation between these two magnitudes of the form

$$\Delta p.\Delta x \geqq h \qquad (1)$$

This conclusion constitutes the generalization which is known as Heisenberg's Principle of Indeterminacy, and while it does not enable us to make any calculations on the behavior of atomic systems and electrons, it is extremely important in indicating the nature of the predictions which can be made about such particles.

Heisenberg's principle postulates that there exists a *fundamental limitation* governing the possibility of associating exact determination of position with exact determination of momentum, when dealing with such systems as atoms and electrons, and the reason for this is the fact that any observation on atomic systems or electrons involves an interaction with agencies of observation, not belonging to the system. Thus the *initial conditions* in any dynamical problem involving atoms are *indeterminable* to the extent defined by equation (1), and consequently we can not expect classical methods to be valid for calculating the behavior of a microscopic system such as an atom or an electron.

What, then, can be calculated with regard to the behavior of such a system? In the ordinary affairs we have learned to solve such problems by applying the methods of the theory of probability. In the case of atomic systems we can calculate only the probability of occurrence of any event, and the development of a mathematical technique for carrying out such a calculation has been the objective of the new quantum mechanics with which are associated the names of Heisenberg, Schroedinger and Dirac.

Now the most salient feature of this technique is its complete detachment from mechanical models. In the classical quantum theory a hydrogen atom in the normal state was represented by an electron revolving in a circular orbit about a nucleus of unit positive charge. But the new quantum mechanics merely postulates that there exists a field of force due to the nucleus, and then determines what is the relative probability for the occurrence of the electron in a unit volume at any point in the space

surrounding the nucleus. It expresses this probability quantitatively as the square of a certain function, known as an eigenfunction, and designated by ϕ.

One type of mathematics used in determining these eigenfunctions, that of Schroedinger, resembles formally the sort of mathematics used in the solution of problems involving vibrating systems. It is a well-known fact that an organ pipe, a string or membrane fixed at the edges can vibrate only according to a series of discrete frequencies. The different possible frequencies are given by ν_o, $2\nu_o$, $3\nu_o$, etc., where ν_o is known as the fundamental tone. In a similar manner it is found by application of the new quantum mechanics that any atomic system can exist only in a series of discrete energy states, each of which is designated by three quantum numbers. Furthermore, these numbers are not brought into the calculation by any special quantizing principle. They arise naturally in the process of solution and may be regarded mathematically as defining the number of nodes along each of the three coordinate axes used to define the function ϕ. The discrete energy states are known as eigenvalues, and they constitute the mathematical analogue of the discrete frequencies which occur in the solution of problems for vibrating systems.

However, if we speak of this mathematical technique as wave mechanics, we must not infer from this that we are dealing with a physical reality. The term "wave" in quantum mechanics has about the same significance as its use in the expression "a crime wave." It is a convenient fiction, used to represent a magnitude which is a function of all the coordinates of the different particles constituting the system. For instance, in the case of the helium atom, the eigenfunction is a function of six coordinates, corresponding to the three coordinates required for each electron.

This conclusion regarding the nature of the eigenfunctions is also deduced from the fact that we can derive the same results by a purely symbolic mathematics which makes no appeal whatever to any physical analogy. This is the technique devised by Heisenberg and Dirac, which uses the algebra of matrices and operators. To attempt to explain this type of logic, in a discussion such as the present, is impossible. The important point is that this apparently non-sensical kind of mathematics leads to conclusions which are in agreement with the experimental observations on the behavior of atoms and molecules. The mathematics merely acts as a calculating machine. At one place we insert such fundamental relations as we know are valid experimentally; then we turn the crank, and after much manipulation and groaning of the gears, certain results appear, and they involve other relations which may be subjected to experimental verification.

Let me illustrate by considering the problem of the interaction of two hydrogen atoms. We know that each atom consists of a nucleus of unit positive charge and an electron. What happens when two such systems are allowed to approach very closely? We have, to start with, the fact that each of the four particles, the two electrons and two nuclei, exert forces of attraction or repulsion on the other three particles—and that these forces must vary inversely as the square of the distance between any pair. But we also know this—that because of the principle of indeterminism, it is impossible, when the two atoms are close together, to identify each electron with a particular nucleus. The electrons are constantly interchanging places, and by no experiment can we ever keep track of each electron separately. We now insert these facts into the Schroedinger equation, that is, the calculating machine, and proceed, according to definite rules, to manipulate the equation. The deductions that are obtained are quite novel. For one thing, we learn that there is only one chance out of four that the collision

of two hydrogen atoms will result in molecule formation, while there are three chances out of four that the atoms will collide elastically without molecule formation. Furthermore, it is possible to calculate the heat of formation of the molecule, and we find that electrostatic forces of attraction and repulsion account for only about 10 per cent. of this energy, the other 90 per cent. is due to what are known as exchange forces, because they arise from the possibility of interchange of the electrons in the two atoms. Thus, the homopolar or shared-electron bond expresses to a large extent this exchange energy, for which we can not find any physically satisfactory representation.

Another well-known illustration is the interpretation on the basis of quantum mechanics of the observations on the rate of disintegration of radioactive elements. In classical mechanics a particle at the bottom of a valley must certainly remain there until pulled out by an external agency. But in quantum mechanics, we find that if the hills surrounding the valley are not too thick compared with atomic dimensions, then there is a definite probability, if the particle has sufficient kinetic energy, that it will "tunnel" through these hills and thus escape permanently.

This theory of the penetration of corpuscles through potential barriers has made possible a quantitative interpretation of the rate of emission of alpha particles by the nuclei of radioactive elements, and has been applied in other fields with equally satisfactory results.

Perhaps you are now in a position to sympathize with our friend Alice:

> "I can't believe that!" said Alice.
>
> "Can't you?" the Queen said in a pitying tone. "Try again, draw a long breath, and shut your eyes."
>
> Alice laughed. "There's no use trying," she said, "one can't believe impossible things."
>
> "I daresay you haven't had much practice," said the Queen. "When I was your age, I always did it for half an hour a day. Why, sometimes I've believed as many as six impossible things before breakfast."

To an older generation, brought up on the mechanistic views of the latter part of the nineteenth century, all this new type of calculus appears incomprehensible. There is a popular belief that this cryptic symbolism is only a temporary phase in the development of a more comprehensible representation of nature, and even so great an authority as Sir James Jeans implies this opinion in his work, "The Mysterious Universe."

> The essential fact [he writes] is that *all* the pictures, which science now draws of nature, and which alone seem capable of according with observational fact, are *mathematical pictures*.
>
> Most Scientists would agree that they are nothing more than pictures—fictions if you like, if by fiction you mean that science is not yet in contact with ultimate reality. Many would hold that, from the broad philosophical standpoint, the outstanding achievement of 20th century physics is not the theory of relativity with its welding together of space and time, or the theory of quanta with its present apparent negation of the laws of causation, or the dissection of the atom with the resultant discovery that things are not what they seem; it is the general recognition that we are not yet in contact with ultimate reality. To speak in terms of Plato's well-known simile, we are still imprisoned in our cave, with our backs to the light, and can only watch the shadows on the wall. At present the only task immediately before science is to study these shadows, to classify them and explain them in the simplest possible way. And what we are finding, in a whole torrent of surprising new knowledge, is that the way which explains them more clearly, more fully and more naturally than any other is the mathematical way, the explanation in terms of mathematical concepts.

Perhaps we might be so bold as to suggest that the so-called shadows themselves may constitute the only reality we can ever attain. Indeed, if we were philosophically inclined, this would be a most opportune excuse for discussing the problem "What constitutes reality?" But I have an impression that the question may be meaningless from Bridgman's point of view, and that the old Persian poet's opinion still holds valid:

Myself when young did eagerly frequent
Doctor and Saint, and heard great argument
About it and about: but evermore
Came out by the same door where in I went.

Why should nature be patterned after those physical concepts which we have formed on the basis of a rather limited experience? That we have found certain representations to be useful in dealing with such dimensions, velocities and masses as we meet with in everyday experience, is no *a priori* reason that the same models and same mode of reasoning should be applicable when we are dealing with either cosmic or atomic phenomena.

It would, indeed, be much more marvelous if this extrapolation to both the infinitely large and infinitesimally small were valid. Since, however, it has been found that such an extrapolation leads to conclusions in contradiction with observations, why should we not recognize that nature is essentially complex and that concepts which have proven useful in one region of experience may have to be modified profoundly when we wish to describe other regions? However, we must demand that in passing from one class of phenomena to another class, the transition in concepts be not made abrupt that is, *per saltu*, but continuous. Speaking mathematically, we can not permit any discontinuities in the slope of the curve which represents any one aspect of natural phenomena.

Now it is of extremely great significance that the new quantum mechanics represents just such development of classical mechanics. For it may be demonstrated that for large scale phenomena, the mechanics of Schroedinger or Dirac yields solutions which are just as precise as those derived by Newtonian mechanics. In other words, as we proceed from microscopic or atomic systems to those which are macroscopic, the probability increases more and more that the constituents of a given system will occur in definite regions of space with well-defined velocities, depending upon the initial conditions and law of force which is valid for the particles.

It is in this sense that we can regard both the theory of relativity and the new quantum theory as representing an evolution of our ordinary physical concepts which enables us to carry out calculations in the region of the infinitely large as well as in that of the infinitesimally small.

The history of the progress of physical science during the past three centuries presents us with many developments which are similar in nature, if not in content, to those of the present. In the time available it is possible to consider briefly only one or two illustrations of this statement, but actually the number is quite large.

One of the most fruitful concepts is that of the kinetic theory of gases, which originated in the middle of the nineteenth century through the work of Clerk Maxwell and Clausius. The pressure of a gas is due to bombardment of molecules on the walls; the temperature of a gas is a measure of the kinetic energy of motion of the molecules. But note how from such simple concepts we evolve the more complex ideas of temperature as a statistical magnitude, and of distribution functions with respect to velocities and coordinates. From this there evolves in turn the whole of statistical mechanics, the principle of equipartition of energy and the notion of entropy as a probability function. And speaking of entropy, we are reminded of the allied concepts of free and total energy.

These concepts fulfil in thermodynamics the same purpose as the potential function in classical mechanics, and thus make the law of conservation of energy the bond between the science of heat and that of motion.

But let us consider further the path along which we are led by the kinetic theory of gases. We have spoken of the

principle of equipartition of energy. It proves a veritable "sesame" to the observations on specific heats of solids and gases, and even to the laws of black-body radiation. But, note, there are some discrepancies, slight at first, but increasing in magnitude and number as our measurements become more refined. What is wrong? And the answer comes at the threshold of our century with Planck's theory of energy quanta. The principle of equipartition, we find, is true in the limiting cases of high temperatures and low gas pressures. At lower temperatures and higher pressures we must modify our original concepts and introduce the new idea of energy quanta.

Hence arises the Bose-Einstein form of statistical mechanics, which achieves for radiation or light corpuscles what ordinary statistical mechanics accomplished for material corpuscles.

However, a difficulty arises when we come to apply statistical methods to the electrons in a metal. The Drude-Lorentz picture of a current in a wire as due to streaming little carriers, each loaded with a unit electric charge—this representation is very realistic, beautifully so, and works after a fashion. But the model leads us to wrong conclusions in many cases. We know that the electrons in a metal must behave as a gas at extremely high pressures. Furthermore, we know from the experiments of Davisson and Germer that electrons in motion also behave like waves. A reconciliation is found in the Fermi-Dirac statistics, which shows how the transition may be made between a statistics devised for ordinary gas pressures and high temperatures and another form which must be valid for low temperatures and very high pressures. Also, Bloch, Peierls, Bethe and others show that by the introduction of the wave concept certain other observations on the behavior of solids may be interpreted much more satisfactorily.

All these achievements have involved a constant extension of concepts which originally were intended to give us mechanical models of the phenomena about us. But gradually the concrete model has faded out and vanished, to be replaced by a mathematical logic in which all the anthropomorphic and subjective aspects no longer appear. Always the efforts of the great contributors towards the progress of science have been directed from one point of view—that of eliminating from our concepts their residual traces of animism, tradition and dogma.

There is a suggestion here upon which, in view of the present state of world events, we can not help but dwell for a moment. In fact, the noted historian, James Harvey Robinson, has written an essay entitled "The Humanizing of Knowledge," in which this thought has been developed in a most interesting manner.

Perhaps, the scientist may be a Moses crying in a wilderness of ignorance and prejudice, but is it not remarkable that science is the only activity of the human mind in which regimentation and dictatorial control of ideas have proven impossible of achievement? Because of this, it may yet happen that the world will be saved for liberalism and freedom of opinion by those unobtrusive workers in search of truth for whom the only ideal is

> But to live by law,
> Acting the law we live by without fear,
> And, because right is right, to follow right
> Is wisdom in the scorn of consequence.

Nature is complex, as mentioned already, and the only feature that is astounding about the whole of theoretical science is this: that human intelligence has been able to devise a method of reasoning with almost transcendental symbols by which a one-to-one correspondence is attained between the deductions

from this reasoning and the actual observations.

If, according to Bertrand Russell, "Mathematics may be defined as the subject in which we never know what we are talking about, nor whether what we are saying is true," then the greatest advantage inherent in the use of mathematical methods is their very generality and complete detachment from concrete visualization. The abstractness of mathematics enables the human mind to think in terms of concepts which transcend the limits of experience and thus opens up new possibilities for interpreting the interrelations of those magnitudes which observation reveals. It is not at all essential that these representations shall be physically comprehensible. For after all the only object of theoretical physics is to develop a set of concepts and rules of reasoning in terms of those concepts by which quantitative conclusions may be deduced. The object of physical science is not to answer the question "Why nature behaves as it does." Rather, it is the ultimate objective of science to describe the universe about us in terms which shall enable us to systematize the various observations and predict as accurately as possible the results of further experiments.

The history of physical science shows us the gradual development of such concepts as would prove most useful in fulfilling this purpose. The "Principia" of Newton, the "Mécanique Céleste" of Laplace and the "Thermodynamics" of Willard Gibbs are representative of stages in this evolution of ideas in which Dirac's "Principles of Quantum Mechanics" will assuredly not be the ultimate. These works, and others like them, symbolize the constant efforts of the human intellect to understand the universe about us—efforts which will not cease as long as man survives. For the greater the extent of the known, the more numerous do the unknown regions become which beckon us on.

Undoubtedly the near future will see further modifications of present concepts. We are just beginning to learn something about the nuclei of the atoms and their transmutations, and further discoveries will be bound to affect our present ideas profoundly. But whatever the future will reveal, of this much we may be certain, that our representations will not be in the direction of the mechanistic models of the nineteenth century and its philosophical attitude of determinism. Far from it. The study of mathematics has opened up many vistas replete with suggestions for new methods which physical science may appropriate and incorporate into its interpretation of the universe. Signs of such developments are not lacking even now, and if we regard the achievements of the past thirty years as a guide, then indeed we may look forward with confidence to even greater progress in the next thirty years.

LEPERS AND LEPROSY

By PERRY BURGESS

PRESIDENT OF LEONARD WOOD MEMORIAL (AMERICAN LEPROSY FOUNDATION)

In dealing with leprosy it is important to have in mind that there are two distinct problems involved. The first is concerned with giving food and shelter to people who are disintegrating into loathsome helplessness. The second, and by far the more important, is that which is concerned with finding the means of eradicating the disease itself.

It is generally accepted that there are not less than three million lepers in the world, and if we were able to detect all those in early stages the number probably would be much greater. Of the positive cases in institutions probably about 50 per cent. are incapacitated for work, and a pitiful handicap is placed on the others, since with a few exceptions the products of the leper's toil has no market. No well person wants that which his leprous hands may produce.

The leper's state, especially in the advanced stage, is such a pitiful one that tens of thousands of dollars and hundreds upon hundreds of kindly disposed lay-workers have been forthcoming to make easier the lot of old men, young women, little children, whose fate could, by no stretch of imagination, be more miserable.

I have visited some twenty countries where leprosy is found and in none of these did I fail to find something, and in many places a great deal being done by governments or private institutions, and in most cases by both, for the leper's physical needs. However, we have, in the main, only begun to work at *leprosy,* since probably not more than 2 per cent. of the world's total of victims of this disease are in any kind of leprosarium and too often these leprosaria are nothing but asylums, with no pretense of giving the inmate medical attention or of trying to get at the solution of the disease itself. It seems incredible, when one stops to think of it, that pretty generally we have thought much work was being done for leprosy if much money was spent on feeding and housing lepers. It seems tragic to see great numbers of lepers herded together and often not one thing being done for them medically; to see literally millions being spent for subsistence and often almost nothing for research. It is toward correction of that condition that we bend our energies.

I have visited leprosaria with as many as a thousand men, women and children stricken by this disease and not a single one of them receiving medical attention of any sort. In an isolated ward of a general hospital I saw a young man, who had been an inmate of one of the leprosaria and had pleaded that he be brought to the hospital so that he could be treated. From a leprosarium, mind you, and even so the treatment being given him was a method that had long been discredited by practically every modern leprologist. On the other hand, I visited one place in Southern China where the lepers had built their hovels among the tombs of a cemetery, as in Biblical times, using for materials frail and perishable branches of palms. In this place I found a clinician and a bacteriologist with modest but adequate laboratory equipment and examinations being made with care and intelligence. As an American I am proud to say that in the United States, where the total number of lepers is probably not more than 1,000 cases, there is maintained at Carville, Louisiana, the finest and best equipped leprosarium I have ever seen.

With twice as many new lepers developing each year as are now in all the leper colonies in the world, I'm convinced that the very fact that so much money is being spent to care for lepers often serves as an actual barrier to any considerable sum being spent in the more important basic studies of the disease.

It is much like attempting to win a war by the single expedient of hospitalizing the wounded. It is humanitarian and right to hospitalize the casualties if we can, but when a war is on the essential thing is to win the war and thereby prevent other casualties.

Segregation has been generally considered as the only means of eradicating leprosy, but with probably not more than 2 per cent. of the lepers of the world in isolation it must be quite obvious that segregation will never solve this problem. I do not want to be misunderstood in this matter of segregation. I believe thoroughly in it as welfare work, and where it can be practiced 100 per cent. it may prove an effective preventive measure. Norway and Sweden are frequently pointed to as countries where that has been done. However, I do not believe that the evidence is indisputable, that even in these instances segregation was the sole factor that led to the diminution of the incidence of leprosy since the disease has practically disappeared from all Europe where only seven hundred years ago there were not less than 2,000 homes for lepers.

One must admire the notable efforts being made in the Philippines and if that government can continue to expend the enormous sums for this purpose that have been spent in the past, reduced somewhat by establishing agricultural colonies, as is now being proposed, this will constitute probably the most thorough experiment as to effectiveness of isolating lepers from the well population that we have ever known. However, we are compelled to grant that after over thirty years of this heroic segregation there is no striking evidence that the number of clinically observable lepers has been decreased. In this same connection I wish to pay tribute to the campaign now underway in Colombia, where the government is making every effort to place all its lepers in a single colony. In this country it is even proposed to burn the houses in which leprosy has existed if a practical method of indemnification can be found.

As a world eradication program, however, segregation is both impractical and useless. How then can we proceed effectively against this disease that has been for centuries one of the greatest curses of the human race? I would urge the building in every country where leprosy is a serious problem of at least one central institution, manned by medical officers with sound scientific background. These institutions may have few or many patients. It is essential that there be enough for research. These centers should perform a three-fold service; first, carry forward investigative studies in the nature of the disease; second, make available to local doctors and institutions reliable information as to the best that is known with respect to treatment; and third, control the propaganda of the country to the end that it may be trustworthy.

We must bear in mind, however, in contemplating this problem that leprosy is a worldwide disease appearing under greatly differing conditions of life. There is, therefore, in my opinion, the necessity, in addition to what is proposed for the individual countries and what is now being done in many of them, for an international organization that will view the matter not from the peculiar conditions that exist in any one particular country, but shall study the facts of the disease as presented in different countries the world over. The Leonard Wood Memorial directs its activities

toward that phase of leprosy. The usual lines of research are being pursued by this and other organizations through individual scientists. We are carrying on bacteriological, pathological, clinical and biochemical studies. While believing that these fields of investigation are important and can not be neglected, they must, however, depend largely on individual inclinations and hunches. Something in addition is necessary. As a layman I can offer no opinion as to what may be possible with respect to other diseases, but in the case of leprosy I believe I am justified in the opinion that there is not only the possibility but the basic need for a thoroughly organized, centrally directed, worldwide, simultaneous, prolonged investigation of the environmental conditions of the leper—climate, food, social conditions, family history, contacts, etc. In other words, a worldwide epidemiological study of all the factors that, by the furthest stretch of imagination, could possibly contribute to the transmission of the disease. It must be clear that had such studies been carried on at any time in the past with respect to malaria, it would have been discovered that the anopheles mosquito was always present when there was malaria, and this fact would have led straight to the villain in the piece. Since leprosy exists under such varying conditions we must seek to learn whether there is not always some common factor present when people become lepers.

In my travel through leper countries two things have impressed me above all others. First, this matter of segregation already referred to and, second, the contradictions of conditions under which leprosy exists. I came to the conclusion that it was possible to make almost any statement about the disease and contradict it by actual example.

I suppose that the one belief that is most commonly held to be fact is that leprosy is not hereditary. Certainly the weight of evidence seems to be on that side.

I traveled one raw fog-ridden day up a winding river along low muddy banks in Southern China. What the English doctor accompanying me dubbed "Her Majesty's" barge, a small sampan propelled by two Chinese lepers, had been sent for us. We stepped ashore in the slippery mud at the boat's landing and were escorted through the old colony, that accommodated some six hundred lepers. A young Chinese boy carried my cameras. He did not look like a leper but, as owner of the cameras, I had some rudimentary interest in knowing whether he was or not. I learned that he was the son of a leper, was born in the colony, had been nursed by his leprous mother and lived in the lepers' dormitories. He had not contracted leprosy. Upon inquiry I was told that there were ten such in that one place.

In Southern China there exist entire leper villages, established by lepers driven from their own communities. They have not been permitted to marry people outside their village. I was told by American doctors that in some of the places it was impossible after three generations to find a single leper. Frankly I think this requires much more careful investigation, but apparently there has been a great decrease in the number of cases, whether it is true that the disease has entirely disappeared or not. It is noteworthy, however, that despite the fact that it has been for so long accepted that leprosy is not hereditary, several scientific workers are expressing doubt that this is true, and since the necessity for revising long-held beliefs in connection with other diseases is not uncommon, it is my opinion that the question of heredity must also be the subject of more thorough study.

Is leprosy easily contracted? The general idea of laymen is that it is highly

contagious. One of the kings of Angkor, that civilization which with its magnificent temples and palaces was for centuries swallowed up in the jungles of Cambodia, was a leper. I saw the statue of the old boy sitting disconsolately and alone on the terrace of the leper king in the city of Angkor Tom, his only companions the monkeys and birds by day and the prowling panther at night. The legend, told the visitor in all seriousness by the Sanskrit scholar who acts as guide, is that this king, returning through Victory Gate after one of his frequent military campaigns, was suddenly dragged from his horse and embraced by his leprous mother-in-law, who wasn't particularly enthusiastic that his majesty was getting a bit fed up with her two daughters and had added to the royal ménage a younger and handsomer wife. Leprosy is supposed to have assailed him with ghastly suddenness. At any rate, it is of interest that one of the Kymer kings was a leper, that he was driven from the royal palace to a special place built for him and that on the deep façade of this terrace there is seen among the sculptured figures of elephants and tigers and monkeys—a crabao tree, the native chaulmoogra, the nuts of which have offered a home remedy for leprosy in Southern China for hundreds of years.

While having a motion picture cutter in New York work on some film of the Culion leper colony, in spite of the fact that the particular print that he was working on was made in his own laboratory, before he would touch it he provided himself with cotton gloves—"just," as he rather sheepishly explained to me, "to be safe." On the other hand, last summer we had occasion to bring a leper to the office of the American Leprosy Foundation in New York City. Not one of the girls in our office had the slightest fear of this man, due, of course, to the fact that their work had given them a knowledge of the disease and how slight the danger of infection.

How justifiable is this great fear of contracting the disease? The case of adults becoming lepers is so rare that some leprologists are of the opinion that it is only contracted in childhood, an opinion that seems hardly justified, however. The last American to be a patient at Culion, for instance, was an ex-Spanish war soldier who had served in the Philippines. His leprosy developed several years later, and he advanced to one of the most shocking disfigurements it has been my misfortune to see. Cases are fairly common in which the patient apparently could have contracted the disease only after childhood.

The weight of evidence seems to be on the side of the opinion that leprosy is not easily contracted. I personally know scores of workers in the disease in every part of the world. The cases of contraction almost do not exist. The few cases that are known can easily be explained.

I visited a small and old leprosarium in Johore in the Non-Federated Malay States. Here were about two hundred patients. Until eight or nine years ago six or seven female nurses and workers, non-lepers, lived in the colony, ate with the patients and slept in the dormitories. Not one has contracted the disease. At Culion, where the leper population has numbered thousands since its founding in 1906 and is 7,000 at present, there has always been a large group of well people, doctors, nurses and others, numbering several hundred. Until very recently there had been no case of one of them becoming a leper. Quite recently a clerk who constantly handled money of the patients has become a positive case, but he had at least one relative with leprosy. In New York City we have twenty-five or so cases all the time and never a secondary case, not a single case, I am told,

contracted in the city. On the other hand, there are places where this disease, having gotten a foothold, has swept through the community like an epidemic.

One day I boarded an inter-island steamer to go from Honolulu to the leper station at Kalaupapa. The boy who had taken my bag around to the cabin which had been assigned to me came back to say that there was a woman in the cabin. When the purser investigated he found she had come over from Kalaupapa on the last trip and had occupied that cabin, and assumed that she was to have it on the way back. Since she had come from the leper colony I made inquiry as to who she was and discovered that she was the wife of one of the lepers and traveled back and forth regularly. Although I am not at all squeamish, going in and out of leper homes without any thought of possibly contracting the disease, at the same time I very generously said that this woman, so far as I was concerned, could occupy the cabin, since I did not intend doing so. It is interesting, however, that there was a case of a well person living with a leper and not contracting the disease, not an infrequent occurrence.

One of the most interesting conditions I have encountered was in Colombia, where there are about 7,500 patients in three leprosaria. These are all to be concentrated at Agua de Dios, which will then be the largest leprosarium in the world. To-day there are about 5,000 patients in this one institution. Until 1931 the law permitted a leper to bring his entire family to the leprosarium and a house was provided for him. To-day there are 2,000 of these well people, and in every case there is at least one leper living in the house, with no attempt made at segregation from the well members of his family. The only segregation practiced has been that the entire family was confined to the leprosarium and could go outside only with permission—a permission, however, that has been frequently granted. Practically no leprosy has resulted, actually a fraction of one per cent. of the population.

Why does leprosy occur in one place and not in another? We don't know the answer to that and if we did know we probably would be hot on the trail of the solution of the mystery.

Why in certain countries is leprosy found only in definite foci? For instance, in Jamaica most of the leprosy comes from two parishes, while in Puerto Rico it comes chiefly from three cities, and in Naguabo, the city from which most of the cases come, a large number of them occur in two streets in the poorer section of the city.

Why do we find it flourishing among the Malay countries; the Philippines, Java and the Malay States in about equal proportion?

Why do we find in certain places in Java low swampy country with much malaria and no leprosy and contiguous territory, high and dry, with no malaria and much leprosy?

Why is it that in certain provinces in Southern China one tenth of the entire population are lepers? Why is it that it is found in that country down in the heavy damp, low countries of the valley and the seacoast and in the snows of the mountains?

Congested population—is that it? Then why is it that with twenty-five or more lepers living at all times in New York City, it is said that there is not a case on record of an individual contracting it in the city? The answer is not racial. I doubt whether the Chinese of Singapore live any more crowded together than those in Chinatown in New York City or San Francisco. I am told that much the same conditions hold in London and Paris as in New York City, a few cases present all the time but no secondary cases.

Why do we find it assailing the Eskimos of Iceland and the Hottentots of Africa, or the Polynesians of the South

Seas? Why do we find it disappearing from Europe, where it flourished only a few hundred years ago and find still a million cases in China where its existence goes back to the beginning of history? Why is it that certain states in our own South have not a little of leprosy with a thousand cases in the entire country? Why is it that in 1856 170 Norwegian lepers settled in Minnesota and to-day the disease has practically disappeared.

We don't know. We only know that its locales are far-flung and differing, but up to the present we do not know the reason.

Is leprosy curable? Leprologists are very chary of the use of the word "cure," as are those who deal with tuberculosis. But progress of treatment has been so slow that until about two decades ago almost no leper had been released as an "arrested case." Now, from many institutions throughout the world increasing numbers are released each year. A discouragingly large number of these paroles relapse. In the Philippines about 3,500 patients have been dismissed during the last ten years as bacteriologically negative. The disease has recurred in about one half of these. Apparently this is not due solely, if at all, to the fact that these paroles go back into the same conditions of living as those from which they came. Very recently there has been conducted at Cebu an interesting experiment along these lines. Five young men, paroled from the Cebu leprosarium, have been taken into the home of a Catholic priest as house boys. This was done for the purpose of seeing whether sanitary living conditions and proper diet would prevent relapse. All these became positive again within a period of from four years to four months, except one. This latter after a two-year period is still quiescent, but this was practically a "burned out" case when paroled.

The most that we can say is that it seems very probable that arrestment has been effected in early cases, but we are a long way from having a specific for the disease.

At Carville, Louisiana, I was shown four lepers (children), all in one family. Their ages range from six to thirteen years. Six years ago the mother was diagnosed as having leprosy, which would have been just about the time the youngest was born. He presumably was in closest contact with the mother and was the heaviest case. The others varied according to their years, the oldest being the lightest. Also at Carville I talked with two women who had been negative for many years, the older one for fourteen. She and her sister have remained at the leprosarium as employes, since they have no other means of support. They were members of a family of nine, the father was seventy years of age, the mother fifty-eight, with seven children, whose ages ranged from twelve to twenty-seven years. When the woman who was telling me the story was quite young she married a man who was found later to have long been a leper. This man, upon their marriage, had come into their home and lived with the family. After four years he died. Within six years all the members of the family were in Carville as patients. An investigation on the part of the uncle failed to disclose that there had ever been leprosy in the family.

We think of leprosy as occurring usually among people of a low economic level. I was much interested to learn, however, from one of the leading dermatologists in Havana, Cuba, that in treating some 1,800 patients over a three-year period, patients drawn from middle and upper classes, he had discovered thirty-nine cases of leprosy. During this same period about an equal number were seen each year at the skin clinic of the general hospital, but only about one third as many lepers were discovered.

And so one might go on interminably pointing out facts which, at least on the

surface, seem highly contradictory. The question which I raise is, if such contradictions do exist, may they not be very significant? These very contradictions or seeming contradictions appearing under such independent and varying conditions possibly can be made to deliver into our hands that factor or those factors that must always be present when an individual becomes a leper, whether it is in Galveston, Texas, or Canton, China.

The foregoing facts, many of them mysterious and contradictory, are some of those that have influenced us to undertake the worldwide epidemiological campaign already referred to. We shall select as the director of this branch of our studies a man of unimpeachable scientific capacity. We shall determine, through the personal visits of the director, those strategic places throughout the world where units of investigation should be set up. This study will accept nothing that is not proved; it will overlook nothing that could possibly be the cause or a partner in the cause of leprosy. It proposes to conduct an epidemiological study in leprosy that for thoroughness will have had few counterparts in the history of medicine.

We will seek to know eventually, and we do not deceive ourselves by believing that any such program is a short one, just what the conditions were in Europe in the middle ages that do not exist to-day; what conditions exist in New York City that do not exist in Manila; we shall seek to know the habits and conditions of life of people stricken with this unspeakable disease.

From such a worldwide study, certain things must eventually come. Here and there facts will be observed that will suggest clues, definite leads for the bacteriologist, for the entomologist, for the biochemist, for the clinician.

Here too will be clearing houses of information and inspiration that inescapably will be felt in lifting the consciousness and improving the medical knowledge and practice in the various countries. It will be easier to at least bring information as to the best that is known and that one improvement, I can assure you from personal observation, would be worth all such a campaign will cost.

Originally this Leonard Wood Memorial was created in memory of a great American, for the purpose of erecting certain buildings in the Philippines and carrying on certain laboratory investigations. But almost from the beginning the opportunities and necessities have forced us into a wider field—the international field.

Now comes this program, bigger in its conception than the entire original purpose that brought this organization into existence, but a program we believe basic to the whole anti-leprosy campaign. This disease, that lays such hands of horror on little children, on fathers and mothers; that tears apart families and sends beloved ones into an accursed exile, shunned and abhorred by their fellows, was old when Hannibal led his army across the Alps and when Christ walked on the shores of Galilee. It stalks through scores of countries and through limitless centuries, a specter of loathsome horror, defying the power of present knowledge.

I believe that the American Leprosy Foundation, the organization of a country that knows little about the disease, has adopted a program that holds real promise.

We therefore to the extent of our financial ability will leave no scientific step untaken that holds any promise of finding the ultimate solution of this age-old curse of the human race.

IN QUEST OF GORILLAS

PART VII. THE LUALABA SHOW-BOAT

By DR. WILLIAM KING GREGORY

CURATOR OF COMPARATIVE ANATOMY AND OF ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY; PROFESSOR OF PALEONTOLOGY, COLUMBIA UNIVERSITY

OUR exit from Albertville was rather hurried and undignified for the reason that our train, after keeping us waiting for two days, departed with exasperating promptness much too soon after dawn on September 28th. Nevertheless we climbed on board a minute before starting-time, while our three boys wormed themselves into a howling mass of black humanity in the third class. Here they soon allowed themselves to be robbed of their little roll of worldly goods, including their precious official cards of identification. Our train meanwhile departed with the usual warning shriek of the whistle and the excited babel of the attendant African public.

Going westward, we went first through the little gorge where the Lukuga River makes off with the overflow from Lake Tanganyika. Thus we were entering real territory of the Congo River Basin, which covers 1,425,000 square miles of tropical Africa.[1] The Lukuga is one of many hundreds of streams, large and small, that collect their tributes of water and earth in solution and pour them eventually into the mighty Congo. The southeastern part of this river system as a whole curves from southeast to northwest, while the northern division, or Congo proper, runs at first northwest, then west, then southwest, picking up the Aruiwimi, the Ubangi and other great rivers on the way. The Basin is excavated in the great central African plateau, consisting largely of ancient granites and schists and constituting the mountains and highlands of the Cameroons, Gaboon, French Equatorial Africa, Angola, Northern Rhodesia, Tanganyika, Urundi, Uganda, the Sudan and Ubangi-Shari. The plateau itself is the remnant of a Tertiary (Miocene) peneplain which was uplifted in Post-Miocene times.[2] The outlet of this gigantic drainage system is in the southwest corner; here the river expands into Stanley Pool, then, as it rolls off the high central plateau, it contracts into the falls and rapids of the lower gorge, breaking through the mountains of the west coast and flowing into the wide estuary from Matadi to the Atlantic.

The floor of the Congo Basin dates back to Permian and Triassic times, since it consists in many places of fine sandstones, shales and clays, often horizontally stratified. The successive series, the *couches du Lualaba* and the *couches du Lubilache*, are collectively equal to the Karroo series of South Africa.[3] Some of these are commonly regarded as lake deposits, and in certain places they contain remains of fossil fishes that are allied with the Triassic fish fauna of South Africa and Australia. Even in that period, according to Veatch, there were local fault basins, which may appropriately be called early rift-basins, and they became filled with sediments containing "fish, phyllopods, and ostracods, the latter two in such abundance that in the Stanleyville region these little crustaceans formed layers of oil shales.

[1] J. W. Gregory, "Africa, a Geography Reader," 1928, p. 165.

[2] A. C. Veatch, Geol. Soc. Amer., Mem. 3, p. 161, 1935.

[3] *Op. cit.*, pl. 9.

—*Photograph by E. T. Engle.*
WAITING FOR THE RIVER BOAT.

These are the Stanleyville beds of the revised Congo nomenclature and are early Triassic.'"[4] After the Upper Triassic there was an enormous hiatus in the fossil record of the Congo Basin, since there are no known fossiliferous deposits representing the entire Jurassic, Cretaceous and Tertiary periods, during which periods this great area stood above sea-level. In any case, it is certain that the modern Congo River system is relatively recent, since only in a few high places have its streams had time to dig down to the deep, underlying Proterozoic and Archaean formations which are so largely exposed in the highlands on the east.

A quite recent Lake Congo occupied part of the territory of the ancient Upper Triassic lakes.[5] Only in relatively recent times was the brim of the basin so elevated that the lake spilled over at its southwestern corner and the present Congo drainage system began to develop as the lake itself diminished.

Consequently, the central Congo rainforest is for the most part a relatively new growth and the teeming animal life that it supports must have entered it from around the margins at no very distant geological date. The chimpanzee, being a relatively bold, inquisitive, aggressive and adaptable animal, has conquered nearly all the forest territory on both banks of the Upper Congo and ranges from Uganda to West Africa. In spite of the wide geographic separa-

[4] *Op. cit.*, p. 163.

[5] Pilsbury and Bequaert, *Bull. Amer. Mus. Nat. Hist.*, LIII, p. 545, 1927.

tion of the eastern and western gorillas, the two groups appear to be rather closely related species, as their characters merge into each other.[6] We do not yet know exactly how their dispersal from their original center or centers was affected by the presence of Lake Congo. Both the chimpanzee and the gorilla are closely related to certain fossil anthropoids, which in Miocene and Pliocene times ranged from Spain across France and Austria to India; so that the ancestors of the chimpanzee and the gorilla may have come into Africa by different routes from the north, but the eastern and western gorillas must surely have come from a common stock. The eastern or Kivu gorilla, being especially adapted to live in the cool heights of the mountain forests and being an outlying member of a genus which has its headquarters in the forests of West Africa, may provisionally be regarded as an emigrant from that region.[7]

Late that afternoon (September 28th) we arrived at Kabalo and had our first view of the peaceful, muddy Lualaba River as it wandered northward on its way to the Congo. Here the river was flowing gently along a broad open flood plain with low hills in the background.

The porters who carried each of our fifty-eight pieces of baggage off the train and stacked it up on the boat pier gave vent to their feeling for antiphonal music:

[6] H. J. Coolidge, Jr., Mem. Mus. Comp. Zool., Harvard College, Vol. L, No. 4, 1929.

[7] The alleged occurrence of forms that are intermediate between the chimpanzee and gorilla is very dubious; it is usually due to the fact that, with few exceptions, hunters do not know the most essential differences between the two. But of hundreds of chimpanzee and gorilla skulls that have been studied by qualified experts, no one has ever been recorded that showed really intermediate characters either in the molar teeth or in the nasal bones or in other features that easily distinguish chimpanzee from gorilla skulls.

—*Photograph by J. H. McGregor.*

ALONG THE LUALABA.

"AdamanEEE," quoth Crosspatch, as he heaved up each steamer-trunk, gun-box or camp-roll.

"Nwoakoa," groaned Tatters, as the load settled on his tough old head.

I took a stroll about the straggling town, which included perhaps a dozen different shops or "trading posts," and was well rewarded by some choice bits. In the middle of the main square sat the skull of an immense elephant. This animal, I learned, had killed a black or two, the rest had retaliated by killing him, and after feasting on him and selling his tusks, they had set up his head in the market-place as a trophy. Next, I found a series of remains of native picnics containing grisly souvenirs of many old friends often studied in the museum but never before on their native heath: there was the parasphenoid bone of a huge catfish, together with fragments of its skull; here, the lower jaw of a succulent young hippopotamus; then the skull of a much larger and fatter hippopotamus, and lastly the bleached skull of what must have been an extraordinarily tough old buffalo. I took a little stroll in the open fields but could scare up only a few lizards and they ran under the roots of an old tree which must have died from St. Vitus's dance, so wiggly were its branches.

Our excellent dinner in the station agent's house was further cheered by some extraordinary large geckos, which persisted in running upside down on the ceiling, leaping at the flies and playing tag and hide-and-seek with each other with the utmost abandon and disregard of the law of gravitation. If a house-gecko ever reflects on his human landlords, he must judge them to be curiously limited folk who are denied the freedom of the walls and the giddy joys of pursuing fat tarantulas and conducting topsy-turvy courtships on the ceiling.

In the evening we had to go to sleep on the seats in the train and let the mosquitoes bite us until the river-boat arrived late that night. But our daily dose of quinine, taken ever since we landed in Africa, seemed to make us malaria-proof. Anyhow we were glad to get into our narrow but mosquito-netted beds on the boat.

Early in the morning we started north, down the river. The steamboat was flat-bottomed with a surprisingly shallow hull; it was propelled by a rear paddle-wheel, operated by a big crank shaft on either side. The water was unusually low, so that we had to feel our way along the narrow channel; on either side of the bow a black boy took soundings with a long bamboo pole marked with red and white bands and called out the depth to the pilot, who could probably also see the readings from the pilot-house. Several times we anchored in mid-stream and sent out the black boatswain and his crew in a dingy to take soundings ahead; after receiving a favorable report we bumped and partly grounded but backed off, swung clear around and finally just managed to zigzag and pirouette through the shallows.

Here then we were launched at last on that mighty river of our imaginations, the Congo, or, as it is called in its upper reaches, the Lualaba. I was spellbound by its swirling, sucking whirlpools, its coiling trellises of interweaving ripples, its oily pools, its distant broad, flat surfaces that mirrored the tumbling white cloud masses of the African sky. In front of us are low rounded hills and the river swings to the right and then to the left leisurely to find its way around them. The country on either side of the river is rather open, with few or many borassus palms. In the distance the fully grown borassus trees show off well their narrow tall trunks, while their tops look like a compact cluster of palm-leaf fans, except that the borders are produced into long pointed tips. The trunks are slender but with a curious long swelling, followed by a constricted zone near the top.

—*Photograph by E. T. Engle.*

BORASSUS PALMS.

The younger trees have large scales on their trunks and long pointed leaves. A thick grove of borassus palms seen from a distance just before sundown is a beautiful sight, since the light from above is reflected from the trunks and produces a kind of pearl gray mist under the trees.

The destination of this section of our long alternating trip, first by train and then by boat, was Kongolo, where the Lualaba River again becomes unnavigable and all baggage and freight have to be transferred to the railroad link, which carries one north to Kindu. But in the leisurely manner of African travel we had to stay at Kongolo from soon after luncheon to very early the next morning, waiting for the train. We had the advantage, however, of retaining our cabins on the boat, which was tied up at the wharf, and of having our meals there.

Late that afternoon we four took a walk to the rapids of the Lualaba River. On the way we passed through a large native village with broad sandy streets, picked clean of all weeds. Possibly one reason why this practice is so widespread is that it may discourage ants, termites, jiggers, etc. In front of the houses the men reclined, some of them in home-made steamer-chairs. I was told later that native steamer-chairs were first made in imitation of one that was carried by Henry M. Stanley. Their appeal to Africans is surely no less than it is to white men. Here as elsewhere the palms are of great importance to the natives, since they furnish the main pillars, posts, uprights and horizontals, roofing and covering of their houses.

As we neared the river we passed over and between immense boulders containing mica. Evidently the ancient foundations of the continent lie near the surface at this place, so that the river has carried away the later formations. Near the mission, however, I found some ledges of horizontal sedimentary rock, evidently of much later date than the old crystalline rocks of the rapids and probably representing the *couches du Lualaba* of the geologic map.

At Kongolo we saw also the Catholic mission, with its substantial brick buildings; a "white sister" crossed the chapel yard and then we heard the people chanting vespers. I wondered whether the natives conform to this religion in spirit as well as they do in letter; for notwithstanding its manifest outward advantages, its viewpoint and cultural traditions are naturally in conflict with their age-long traditions and ways of life.

Returning to the boat for the night, we took the train early next morning

—*Photograph by H. C. Raven.*
UMBRELLA TREE.
THE LEAVES SUGGEST NEBRASKA WIND-MILLS.

and traveled in a northwesterly direction parallel to the river. Here for the first time we found ourselves passing through patches of the typical Congo forest, containing very tall trees mostly

—*Photograph by H. C. Raven.*
WEAVER-BIRDS' NESTS IN PALM.

with fairly slender light trunks. At one train stop I snatched a twig from an "umbrella tree" (*Musanga*), one of the most abundant trees in equatorial Africa, the large leaves of which suggest a Japanese parasol which has been subdivided radially along the sticks. The trunk of a typical umbrella tree shoots up to a considerable height and then gives off a radial cluster of branches, which again divides and subdivides in much the same way.

As we sat in the swaying dining-car at dinner that evening, a rather lively altercation broke out between two of our fellow passengers. A very stout and grouchy old person had had too much to drink and became fairly voluble, finally making some remarks that offended a lady. Her husband loudly reproved the old man, who, however, was unrepentant and replied in kind. The rattle of denunciations, sarcasms, expletives and other verbal musketry, which French and Belgians shoot with such deadly precision, continued until the old man grumbled himself into a doze. The train arrived at Kindu and we spent the night in our berths there. The next morning the old man, now sober and possibly regretful, must have apologized, for at luncheon the two men were very polite to each other as they sat at the long table on another river boat, where we all once more found ourselves.

This stretch of the river was very wide and flat, the surface swirling with circles and great irregular oily polygons. On either side the forest was quite dense and we began to see native villages along the level banks. Every few hours we would tie up at a little settlement along the bank and take on a load of wood. In landing, a superbly developed black of the burly forest type would leap overboard near the bow, with a steel cable dragging after him; with a few mighty strokes he would swim to the bank, drag out the cable and tie up the boat. Mean-

while another black would be doing the same thing at the stern. Then a huge flat plank would be shoved out from the lower deck to the bank; a wooden horse would be placed under its farther end and a second wooden plank would complete the bridge. The white folks would walk off to see the local sights and some of the amusing black passengers would rush ashore to buy food, while others would come on board.

While stopping for an hour at Wayika we were hospitably greeted by the Reverend Dr. Whitehead and his wife, who have for many years conducted a mission at this place. Together they have compiled a dictionary and grammar of Bangala, the western dialect of Swahili. This excellent work, two copies of which we purchased, is printed and bound in Mr. Whitehead's printing establishment by black assistants to whom he has taught the entire business of typesetting, proofreading, printing and binding. Here also are printed government reports and orders. This is an interesting example of what native Africans can do under wise management.

Mrs. Whitehead told me an episode of their missionary work, which had recently taken place. They knew that some of their converts were still "worshipping idols" while also attending the Christian service. So the good pastor called a council and told the natives that they must make a final choice between "the living Christ and a dead tree." After much discussion the natives declared which side they were on and brought a great wooden fetish made out of the trunk of a tree, which was supposed to be the dwelling-place of a powerful spirit. This was solemnly cut into small pieces and the pieces were then burned amid the acclamations of the people and the grateful prayers of the old couple.

—*Photograph by H. C. Raven.*

MAIN STREET.

During the long hours of our trip down the Lualaba I amused myself by making crude sketches of the endless

panorama of the Congo forest. As I was utterly lacking in training the only thing in my favor was a strong urge to get the scene down in my notebook before it disappeared. But naturally many technical problems arose, such as how to make a body of water look flat and yet show surface features, how to make limits for clouds that had none, what values to give to clouds, sky, river and forest, and the like. With these puzzles to amuse me, the time passed all too quickly.

After about a day's journey north of Kindu the river became too shallow for our big boat to go any farther; so in the afternoon we tied up at a little village to wait until the next day for a much smaller steamboat that was being sent down from Pontierville to meet us.

Here then was my first opportunity to take a walk in the real Congo forest, so I climbed up the steep river bank and, with Matambele trailing behind me, followed a small path that led through the village into the forest back of it. Here the trees were literally so high that one had to throw one's head away back to look at their leafy tops. The forest was dim and silent except for the soft thud of a hornbill's wings and for its raucous call. In a few moments I saw a slight stir in the treetops and then a small troop of monkeys fled with great leaps from tree to tree. Next we stepped over a train of ants, with many aggressive soldiers raising their mandibles in the air. Afterward we came across a single ant that was the Goliath of its tribe. One look at its mandibles confirmed my suspicious that I would not care to pass the night sleeping on the ground in that forest.

Shortly before sunset we returned to the village, which consisted of a long row of mud huts on a high bank facing the river. Everybody was either seated in front of the huts or looking out of the doors. Just at this time two men were paddling wildly about the river in pursuit of a tame duck that had escaped. They would try to head it off and zigzag toward it but several times it cleverly dived under the canoes just as the men got uncomfortably close to it. The village was all agog and every one found time to broadcast advice to the duck-hunters as well as to jeer when they upset. But the duck had to reckon with an amphibious opponent, for one of the men paddled up close to it and then dived quickly from his canoe, catching it in a few strokes.

Before the buzz of this excitement had died down the Nordic-looking captain of our steamboat strolled up. He was taking his wife's two immaculately white toy Spitz dogs out for an airing (the captain and his wife, by the way, had a regular palm-garden on the top deck of our steamboat). Then up came a yellow dog of the village to investigate. His advances toward these queer white strangers were peaceful enough but somewhat overfriendly. "Grrrrr, spitz!" snapped the little rascals, visibly snubbing their poor relation. In the eyes of the human natives this display of superiority seemed to increase the value of the disagreeable canine visitors. One very old woman, whose loss of several fingers and toes had not dulled her sense of humor, asked the captain what price he would take for the pair. "Ten thousand francs each, in advance," said he, and the bystanders yaw-hawed with a display of shining teeth that would be the envy of any salesman of American dental supplies.

The next day we were met by the small steamboat, which carried us over the rapids and shallows south of Lowa. But the only way that the contents of a large boat and a large barge attached can be dumped into one that is only a fraction of its size is by relying on the time factor, which has a very low value in tropical Africa. The small boat acted merely as a ferry to carry us a few miles to another big boat which had come down from Pontierville.

—*Photograph by H. C. Raven.*

PASSENGERS ON THE TENDER.

This morning we thought that two of our boys (Poussini the cook and the round-faced, large-eyed Musafiri) had deserted, for they were missing. We were wondering what they would do in this strange land, as they had been much depressed at being so far away from home. But when we came up to the big boat there were the rascals still sitting in the wholly dejected manner of Jeremiah but waiting faithfully for us. They had been transferred in the first of the seven loads carried by the small boat to the big one.

The big steamboats on which we traveled always had a load of third-class black passengers stowed between decks, behind the woodpiles and in front of the boilers. These good people had paid their fares just as we had done and possibly at a proportionately higher rate, but aside from bare transportation it can hardly be said that they were getting much for their money. However, the miserable accommodations did not seem to discourage them in the least and every woman waited patiently for her turn at one of the two "stoves" where they could bake their native bread. But there was another class of passengers, traveling in a large metal tender, shaped somewhat like a canal-boat, which was tied to the port side of our steamboat. These people had the privilege of sitting on the deck of the tender, if they were lucky, or of stowing themselves around their baggage in the shallow hold. They were for the most part either soldier police or gangs of road workers, usually with their families. As our staterooms and deck chairs were on the main deck above, immediately facing and looking down on these people, I could study them as much as I cared to without seeming to myself to be unduly rude and prying. For their part, the fact that they had no more privacy than the traditional goldfish did not appear to disturb them in the least.

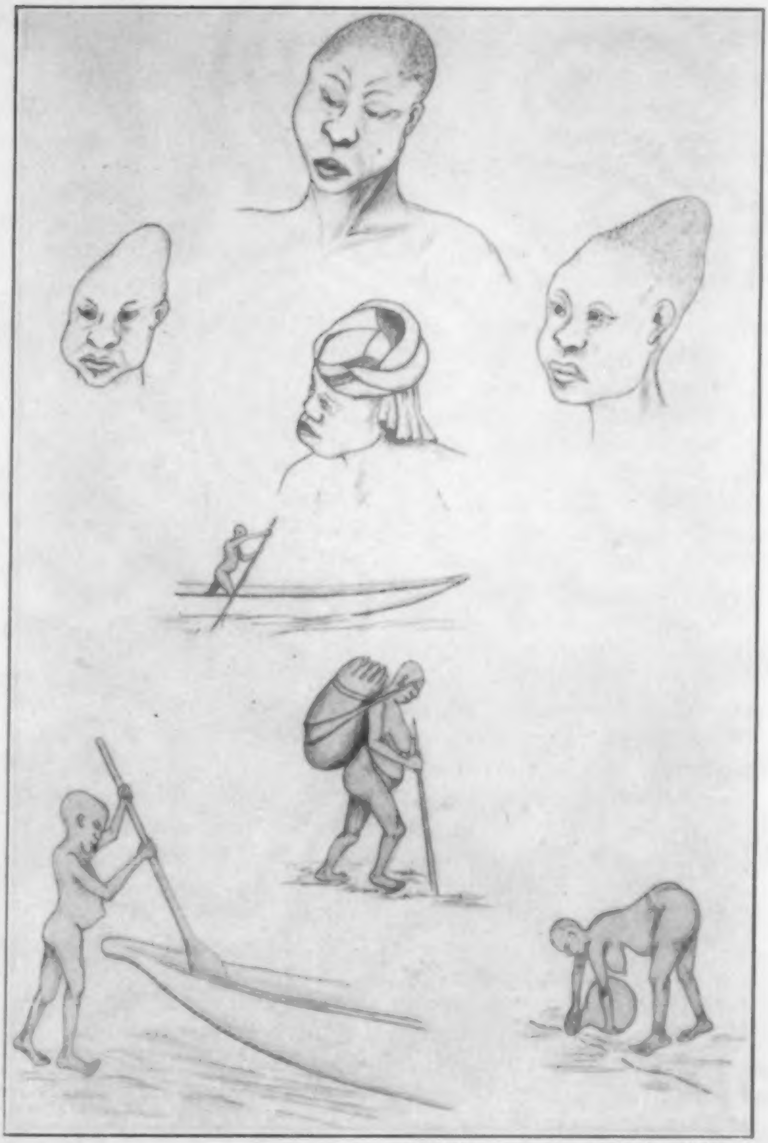
Probably most of these people were

either the children or the grandchildren of savages, who a generation or two ago had been greedy for human flesh and had practised horrible and revolting burial rites. And yet here they all sat huddled together like cattle in a hold, but in perfect peace and apparent good humor, exemplifying the doctrine of "live and let live" and not fearing either the violence of their fellow-men or the capricious vengeance of the gods. Such are among the real benefits conferred by the benign but firm rule of the King of the Belgians.

Signs were not wanting that the new Africa, copying the white man's ways, will have its social grades like any small town. For among the *hoi polloi* in the tender there was one dame of some distinction who sat as aloof as possible from the common trash; she was quietly dressed in gray, with a green parasol, and she spoke only to her handmaiden and to her husband. He, worthy man, was faultlessly attired in a Palm Beach suit, or its equivalent, and wore shoes. But remembering perhaps that he was after all of the same flesh and blood with his less fortunate fellow-passengers, he exchanged civilities with them, quite content to let his habiliments speak for him.

The domestic relations of the African families in our tender afforded some evidence that, however lazy he may be at home, the average *pater familias* is a real helpmate while on a voyage. As often as not the men took care of the small babies and one father of two tiny girls gave an amusing exhibition of forbearance. When the boat tied up at a wharf he took them both down to give them a bath. One infant sent up a fearful uproar the moment the water touched it, opening its mouth to an unbelievable degree and kicking and squirming. The father said not a word and neither frowned nor smiled, but went ahead in the most thorough way, bathing the baby on all six sides and conscientiously inspecting each little toe for chiggers. Then he gently set the still squawking baby down and began the operation on the other one. This one was very good and made no outcry. The father said nothing again; even when the job was finished he picked up one under each arm, came back to the tender and handed both to the mother without a word of complaint or comment. Probably this man when a boy had served a long apprenticeship in the care of his younger brothers and sisters.

At one of the stations south of Pontierville the scene along the bank where we stopped was quite theatrical. High buff-colored bluffs were on either side of an open space and in the background a flight of steps carved in the earth led up to the village on top of the high bank. Brilliantly attired villagers were coming up and down the steps. A tall old half-Arab with beard and aquiline nose was standing haughtily on one side looking as grim and baleful as Milton's fallen Satan. But the chief figures were a group of belles, perhaps the most distinguished-looking lot I saw in Africa. Some were passengers on our boat who had stepped off to greet their friends in this village. Several of the young girls had such mild and radiant faces that for the time being I even stopped admiring the superbly broad noses and semi-anthropoid mouths of the old males. But towering above these minor graces was a sable Juno with high cheek bones and a placid mien. She was easily first among the group and her gestures and expressions were unconsciously regal. Here was nobody's drayhorse but a woman wise in council and fitted to grace the household of a great warrior. It was remarkable how well these untutored feminine beings wore the flamboyant patterns of European make, which they had twisted into attractive turbans and mantles. Meanwhile several little boys, some of them with remarkably good wooden models of the river steamer, ran



Sketches from the author's notebook.

RIVER FOLK.

THE "SUGAR-LOAF" HEADS ARE PRODUCED BY HEAD-BINDING IN INFANCY.

up and down the bank hoping to find purchasers, while others dived joyously for small coins or leaped for cigarettes thrown from the deck. Thus the passing show was continually dissolving into new and exotic scenes, which were brought to a close each day by sunsets of incomparable splendor.

> There the ponderous Lualaba,
> Flowing freely on its way,
> Moved with calm deliberation
> Without flurry or detention
> To its union with the Lowa
> And another flawless day.

At one place where we tied up for the night was a small island, across which we walked. Many cheerful birds were there among the tall trees, especially parrots. On the other side of the island the shore was a cut bank of horizontally stratified shales, laid down by the ancient great lake of the Congo Basin.

During the daytime we were slowly passing the changing panorama of the leisurely Lualaba: now groves of stiff borassus palms in a great flat field; now thatched villages strung along the high steep bank, with many banana plants growing behind the neat houses; now the endless variety of the great forest with its many very tall white-trunked trees and its riotous bushes along the banks. In the river itself the muddy currents were always swirling and sucking as we came toward flat sand-bars or toward a clump of jungle on an island. Occasionally one could see in the distance the head of a submerged hippopotamus, but as a rule these beasts avoided the steamboats, where so-called civilized persons still delight in taking pot shots at them; once in a while by some mischance one finds the mark and raises a spout of blood from the voluminous interior of the poor leviathan of the rivers.

At another station south of Pontierville, where we took on wood and tied up for the night, I took a short stroll into the forest behind the village. The underbrush was not nearly so formidable as at Tschibinda and if one wanted to leave the path one could travel in almost any direction without using a machete. On the path I saw a large cylindrical thousand-legs, dark in color with red spots. Its tiny feet, projecting along each side in a continuous row, were moving in beautiful waves which passed along the body from rear to front. The beast was armored with circular segments of dark shining chitin. Perhaps it had been wounded somewhat, for several ants were investigating it, looking perhaps for a chink in its armor, but it turned and tried to seize them in its rather small jaws.

A little way farther along the path I saw a large and decorative spider with a brilliant red patch on its back and with long legs ending in hooks; it was in the middle of a huge circular web attached to a stem. I gently touched the web with my stick to see what the spider would do. Immediately it began to make the web vibrate with extreme rapidity and repeated this maneuver several times whenever I touched the web or made a swift whirring movement with my stick. Did it by this strange reaction increase its chances either of entangling the prey or of confusing the enemy?

In due time our boat tied up one afternoon at the wharf at Pontierville and all our baggage was transferred to the train for the last lap of our journey to Stanleyville. While waiting for our baggage I witnessed another example of the patience of natives toward their children. The soldier-police had disembarked from the tender and their wives were struggling up the grade with the baggage, small children and babies. One small child went far ahead and took the wrong turn of the path. The mother screeched at it in no uncertain tones, but when she overtook it she did not cuff it or beat it

—*Photograph by E. T. Engle.*

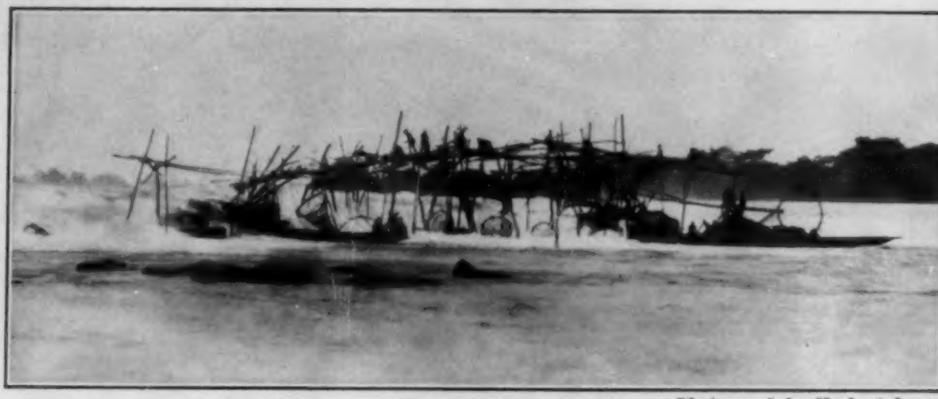
SILENCE.

but simply pushed it in the right direction and it yielded more or less gracefully. That seems to be their technique: steady pressure in the desired direction, while arousing as little opposition as possible.

Pontierville is rather a showy little place, a kind of botanical garden, with pebbly walks and many tropical trees, white shops and a red brick hospital. But at that time the forest was always calling me and I sneaked off to it in a few minutes. After less than half an hour's walk along the railroad track away from the boat-wharf, I found an inviting path into the forest. At first there was nothing unusual, but after I had crossed a clear brook I heard movements in the trees and I stood quite still behind a trunk. A number of monkeys with conspicuous white spots across their faces and with long dependent tails that swung like pendulums were chattering and leaping about among the branches. As they moved away I tried to follow them cautiously, but they soon caught sight of me and made off. This was the best view of wild monkeys that I got anywhere in my travels.

After dinner on the boat we went aboard the train and settled ourselves on the leather seats for the night. The black engineer was fully conscious of his exalted and enviable position and as we passed through village after village his whistle shrieked a warning to the inhabitants, many of whom were lined up to respond with cheers and a clamor of greetings to the carload of natives in third class. Our three black boys were in this car too and bearing up quite well under the circumstances. At first they had allowed somebody to steal their matting-roll, containing their tickets, medical certificates and precious employment books. Also, when only a week out from Uvira, one of them had expressed the opinion that we surely must be getting near to Europe. But by this time they were citizens at large and not taking any mutilated centimes from anybody, although still with the fear of the brass ring about their necks on account of having lost their credentials. In spite of the "poncho" or food money, each one would frequently come to sit dejectedly on the wharfs in front of us and would respond "Chukula hapana" (no chop) with an air of settled despondency which would have moved a wooden image to compassion and the disbursing of "matabish."

Next morning (October 5) it was with no slight joy (although the weather was still abominably gray and chilly) that we debarked on the shore of the mighty Congo River and looked across it to the widely extended city of Stanleyville. This city is almost exactly in the center of Africa and only a few miles north of the equator. While waiting for the little river boat that was to ferry us and our



Photograph by Herbert Lang.

A THRILLING BUSINESS—FISHING FROM A FRAIL BRIDGE BELOW THE FALLS.

baggage across the river, I had the pleasure of recognizing that the dark red sedimentary strata upon which we were standing probably represented part of the great Lualaba formation, which in many places rests on the crystalline rocks beneath. A few days later at the falls near Stanleyville I saw great ledges of this formation which had been cut through by the river. The natives also had evidently acquired the habit of collecting the slab-like pieces of this rock and of piling them like cords of wood into measured quantities marked by posts and wicker rods.

Arriving at Stanleyville we found the main hotel full and had to put up at a very poor second, where the food, rooms and service were as expensive as they were bad. That afternoon I started for the famous Stanley Falls southeast of the town, but by taking the wrong fork of a three-way crossing I finally found myself away out in the country. However, I did not regret the walk as I saw several things of interest that afternoon. In Stanleyville, like so many cities in the Belgian Congo, the excellent auto roads lead for miles in every direction and are lined by rows of oil palms. The road along which I walked had in many places been cut through enormous termite nests, which formed hills twenty or thirty feet high. First I went past the barracks, an extensive place where hundreds of soldiers live with their families in neat little rectangular houses of brick or of wood. Here was a great flock of noisy weaver birds in a high tree in the middle of the road. After I got outside the town I walked across a coffee plantation to the bank of a river that was flowing toward the Congo.

The most interesting thing I saw was a human footprint in a muddy road, at which I stared as if I were Robinson Crusoe looking at the famous footprint in the sand. This footprint was distinguished by the fact that the great toe was well separated from the others and the whole effect was considerably more ape-like than in any other foot I had seen among all the thousands I had looked at in Africa. I tried to follow this mysterious being, but as I am a very poor tracker I could find only a couple of places further on where the same footprint showed clearly.

> But at Stanley Falls the river,
> Roused to fury by duress,
> Lashed the rocks that barred its channel,
> Reared and plunged in its distress;
> Then with many a swirl and tumble
> And a thunderous roaring sound
> It descends into the Congo
> And comes out on quiet ground.

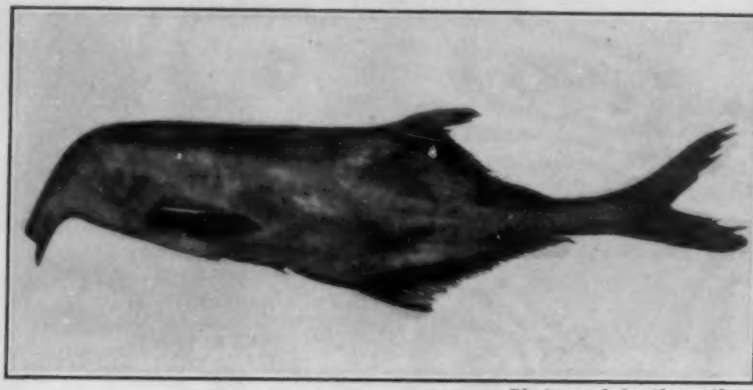
The next day Engle and I walked out to Stanley Falls, passing through a

native village of considerable interest, where the culture of the people seemed considerably richer than anything we had seen to date. Here on top of a high hill was a huge drum, which could doubtless send its booming messages for miles in every direction. Here also were many attractive household utensils, such as little carved bowl-like stools with a circular top and base, finely engraved canoe paddles and many fish traps and trawls, some of enormous size with a great circular opening and an immensely long tapering bag. These were remarkably like the trawls we had used in deep-sea fishing on the Arcturus expedition of the New York Zoological Society (1925) and were assuredly an example of independent development. Then we went down to the river and I had the joy of scrambling over immense ledges of dense dark-purple-red sandstone of the Lualaba series, apparently belonging to the same system as that I had seen at Albertville and Kigoma on Lake Tanganyika.

Another personal joy was a lot of fish-scales and fish bones scattered about on the rocks; first I found a boomerang-like bone with projecting points on its convex side, evidently the left preopercular bone of a large species of *Lates* (Nile perch); next, two hyomandibular bones, probably of the same individuals, next some fragments of the skull of a large catfish. Meanwhile the ledges of sandstone were beginning to show some good potholes, worn by the whirling waters when the river was at flood, and a little further on these potholes became very numerous and of large dimensions so that they left a mottled surface like that of a gigantic Swiss cheese. There were also many enormous boulders of the same massive sandstone, which the river had tossed about as if they were pebbles. We found that the easiest way to progress along this peculiar path was by leaping from rock to rock. This exercise happened to be an early pastime of mine and I was delighted to find that in spite of the passage of years I had retained enough of the simian joy in leaping to carry me safely over these rocky pitfalls.

It is not to be supposed that two queer-looking foreigners could thus go leaping over the rocks and poking about in plain sight of the whole village, peering at empty holes in the rocks, picking up old fish bones and other inedible fragments, without arousing the suspicion that they must be in need of a guardian. So pretty soon we were leading a procession of jabbering comic sketches, each of them volubly insisting that he and he alone should be and hereby was appointed to be our sole official adviser and guide, to conduct us hither and thither in the city of the great chief, and to receive all the rights, perquisites and emoluments pertaining to that office. I suppose it was discourteous, but we resisted and showed our firm intention of managing happily without any guide but ourselves.

Among these funny ones there was a goodly number of black Herculeans with the grandest physiques one could find outside of a gallery of Greek statues. Very soon many more of these black gladiators swarmed down the rocks and got into a fleet of seven great war canoes, all standing with their paddles ready to start. Then the unexpected happened, for they drove those huge forest tree-trunks forward into the roaring current, pushing them up to the base of the rocks below the falls and then letting go, so that the canoe dashed and swirled down the river with dizzy speed. Apparently they were not doing all this just to keep fit, but were somehow resetting the immensely long trawls that were already in the rapids. One wondered how the natives had managed to set up the many stout posts, just above the falls in the midst of the tumbling current, to which their weirs were attached. Two little boys were standing breast-high in a side stream at the head of the falls and fix-



—*Photograph by the author.*

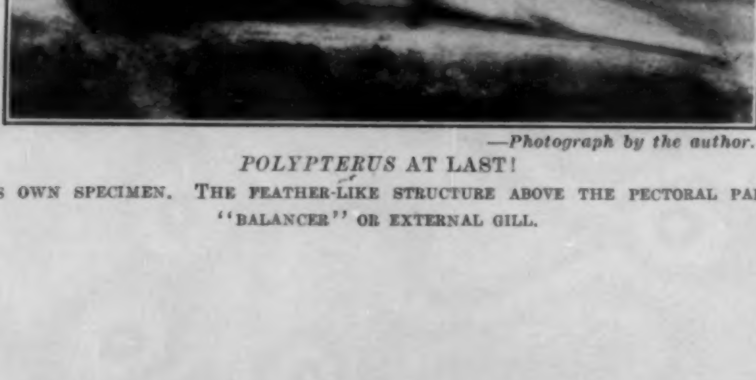
THE SNOOPING MORMYRID.

WELL-EQUIPPED TO INVESTIGATE EDIBLE TIT-BITS IN DARK CORNERS.

ing tiny weirs in a current that would have swept anybody else into the maelstrom. A man dived into the raging pool at our feet and swam about unconcernedly just to show off.

We found a small dead crab which we recognized as being related to those of Lake Tanganyika and soon many small boys were bringing us living samples, one or two of which we took home to McGregor. We made them understand that we did not want those crabs which had rudely shaken off their big claws (as they often do, apparently with the idea of paying tribute to the enemy that has captured them). We had already paid a franc to a boy for a perfect crab, but as he attempted to tie it up for us it broke off its own big claws. A man who had watched us then ordered the boy to give back the franc, as the crab was "no good." But we not only made the boy keep the franc (no great display of force being necessary) but also allowed the man to be our "guide" through the village at the cost of another three cents. If either of us has any Scotch ancestors in heaven, they must have groaned many times over such recklessness on our part.

One morning I got up very early and went to the market, taking Matambele, our chief comic artist, to conduct nego-



—*Photograph by the author.*

POLYPTERUS AT LAST!

AUTHOR'S OWN SPECIMEN. THE FEATHER-LIKE STRUCTURE ABOVE THE PECTORAL PADDLE IS A "BALANCER" OR EXTERNAL GILL.

tiations if necessary. What a treat to find among the fresh fishes a silvery characin, an elephant-headed mormyrid and the very reverend *Polypterus!* In my agitation the negotiations got a bit involved between the owner, Matambele and myself; it appeared at last that I was under the painful necessity of leaving one of these treasures, as Matambele had meanwhile spent most of my metal francs on vulgar food. As rapidly as possible I appraised the scientific value of each of these beauties, which to me at that moment far transcended that of all the sordid metal francs in the Belgian Congo. The characin's claim to distinction was that, according to many authorities, he is a descendant of ancient immigrants from South America, which had crossed along the freshwater streams of an ancient land that once extended from Brazil to Africa. And whether or not this geological fish story be true, the characins are well worthy of an ichthyologist's respectful consideration.

The mormyrid was worthy of preservation not only because the Egyptians had figured him nibbling at the body of Osiris but also because on his own account he was one of the queerest inmates of that fishy madhouse which has somehow been turned loose in Africa.

About *Polypterus* of course there need not be an instant's hesitation. For this heir of all the ages was the lineal descendant of the earliest vertebrates that had tried two dangerous experiments of the utmost importance to us: first, they had begun to sniff their oxygen straight from the air; and second, they had embarked on the greatest real estate transaction of all times, namely, the conquest of all the lands on all the continents, which up to that time had been held exclusively by twelve-inch cockroaches, scorpions and other bad citizens.

—*Photograph by H. C. Raven.*

CLOUDS AND WIND OVER THE LUALABA.

OPEN-BILLED STORKS FLYING ABOVE THE RIVER.

While I was absorbed in these pleasing reflections, perplexed as to the choice between the characin and the mormyrid

and oblivious to the uproar about me, providence decided the matter in a manner very favorable to me, because a corpulent negress made off with the characin under my very eyes, leaving the long-nosed mormyrid and the *Polypterus*, the cost of which exactly equalled the small number of francs still in my possession. After these holy relics had been duly admired and photographed, they were reverently embalmed and laid away in the formaldehyde tank.

One day while we were in Stanleyville McGregor and I, besides going to the Falls already described, called upon Monsignor Grison, the head of the Catholic diocese at Stanleyville, who had made an extensive collection of rocks, minerals and other natural history products of the vicinity. He received us most graciously and showed us his collection. The fossil fishes are of great importance because they indicate that parts of the Lubilache formation, which covers a great part of the Congo Basin, were laid down in fresh water, and because the fishes themselves belong to groups that were characteristic of the Triassic age in other parts of the world and suggest a corresponding age for this great inland lake.

Monsignor Grison also told us several facts of interest about the natives of the vicinity, which at the time of his first coming to Stanleyville, about thirty years ago, still practised cannibalism, at least occasionally. In response to our questions he said that most of the grosser forms of superstition had been done away with, but that some of their own converts sometimes lapsed into witchcraft. We were told by others that the "Leopard Society" probably still existed in secret, and we had seen a mounted group in the museum at Terveuren, Brussels, representing a dramatic murder by members of this choice fraternity. When a certain man is judged to be worthy of death, the members of the society, disguised in leopard skins, meet him in a lonely spot in the woods. The "leopards," who wear sharp claw-like knives on their fingers, then pounce upon him and kill him. They then stamp carved leopard's feet on the path, either as a sign that leopards killed him or as a warning to others to beware of their vengeance. Some years ago, however, the Belgians discouraged this picturesque ceremony by hanging an entire chapter of the order.

(A further article in the series entitled "In Quest of Gorillas" will be printed next month.)

THE BIOGRAPHY OF AN ANCIENT AMERICAN LAKE[1]

By DR. WILMOT H. BRADLEY
GEOLOGIST, U. S. GEOLOGICAL SURVEY

As in olden times, when Kublai Khan held absolute rule over a vast domain and progressively amassed great wealth by reason of the tribute that flowed in from outlying provinces, so in a far remoter epoch, long antedating human history, a great lake held sway over a vast area in the Rocky Mountain region and gradually accumulated in tremendous volume a potential natural resource derived from the sun's unfailing supply of energy and from the mineral burden that flowed in from adjoining lands through its tributaries.

So remote was this epoch that could we go back to it in time we would be compelled to gage our progress by the slow evolution of animal life and the gradually changing expression of the earth's face. We would have to go backward with undreamed-of speed past a pageant of animals that inherited the earth in slow succession as evolution molded them. So short is man's history that it would flit by too quickly to be perceived. Passing backward in a brief moment through the silent ice age, we would see man's primitive ancestors, together with giant sloths, giant bears and beavers and the woolly mammoth. Farther back we would meet small elephants and, on the plains, bands of horses, wild asses and camels. Farther back in time's flight we would find their smaller and ever smaller precursors. Suddenly would appear the hippopotamus-like titanotheres and a host of other strange creatures, each leading a succession of smaller and less specialized ancestors. Finally we would come to the time of the diminutive four-toed horses, which dwelt in the forests and grassy parks of that epoch of long ago when the ancient lake came into its regency.

This great lake, known as "Lake Uinta," occupied a long, shallow basin or downwarp of the earth's crust about a hundred miles southeast of Utah's present Great Salt Lake. The record it left is preserved in the form of an immense body of nearly flat-lying beds or layers of fine-grained rock similar to lithographic stone. This great body of rock is as long as Vermont but considerably wider, and in places it is almost a mile thick. Deep canyons and wide valleys are now cut through it in all directions, so that the whole record is accessible. The thin layers thus exposed bear a remarkably close resemblance to the leaves of a book. Indeed, it is more than a superficial resemblance, for the layers are in fact pages upon which are impressed symbols that portray events of that age so long past.

Modern books are so familiar that we take little thought of their construction and have no difficulty in reading their meaning. But when the earliest written records of man were found they could be read only after learning how the symbols were formed and what relation each bore to modern language. So it is with the record left by the ancient Lake Uinta. Geologists in the seventies of the last century pried apart the stony pages and found that they contained a story about an ancient lake. But the story could be read no faster than the science of geology grew and provided the keys for inter-

[1] Published by permission of the Director, U. S. Geological Survey.

preting the symbols. Moreover, the reading was slow because fragments of the record came to light only piecemeal as exploring geologists penetrated more and more deeply into those parts of the arid West away from established routes of travel. And finally, long passages in the text remained obscure until the study of modern lakes revealed what was taking place in them, for the characteristics of an ancient lake can be understood only by analogy with the lakes of to-day. Thus only recently, as more and more parts of the story have been assembled and integrated into an ordered sequence, has it been possible to learn how complex and varied is the history of Lake Uinta. That history includes a wealth of information, not only about the plant and animal societies that dwelt in the lake itself and on the adjacent land, but also about the ways in which they changed to meet a gradually changing environment. It tells how for thousands of years the lake kept a sort of calendar, by depositing each year a thin layer of peculiar sediment that was sharply marked off from the layers formed the year before and the year after. Though these annual layers do not continue through the whole record, it has been possible from them to estimate that Lake Uinta was in existence for millions of years. The history is more than a recital of elapsed years, however, for it tells both of major catastrophes and of such trivial incidents as the migration along the water's edge of a swarm of small, swollen-headed larvae which, had fate been less harsh, would one day have split their skins and emerged as adult gnats. From this emergence, however, they were prevented by a drop in the lake level, which left them to perish and dry in the sun until the water rose again and deposited on their remains a shroud which it fashioned out of minute interlocking mineral particles.

I

In the beginning the site of Lake Uinta was a broad, nearly level alluvial plain—a sort of huge amphitheater, bordered on three sides by mountains but open to the south. Streams from the mountains wound listlessly across the plain and rested in the grassy marshes. But this landscape was destined to change, for, beneath the plain, the stony shell of the earth was beginning with subtle slowness to warp downward. Thereafter the streams spread broadly over the meadows, changing them to lakes. At first there were two large lakes, but as the downwarping continued these soon expanded and coalesced into a single sheet of water as long as Lake Ontario but much wider. Thus Lake Uinta came into being.

Up from the north shore rose the great swelling bulk of the Uinta Range, its flanks green with forest. This forest may or may not have its counterpart living anywhere in the world of to-day; nevertheless, it must have been much like the forest that would develop on the southern slope of a high mountain on the present Gulf coast of the United States, could we but conjure up a mountain in that region. Just as such a forest would have different kinds of plants growing at successively higher levels, so it is probable that the forest which clad the Uinta Range in that ancient epoch was also zoned according to the altitude. Fossil leaves, flowers, seeds and even pollen grains collected from the bottom deposits of the ancient Lake Uinta enable us to reconstruct the probable floral zones of a landscape that existed during the Eocene epoch more than 30 million years ago.

At the water's edge grew bur reeds, rushes, water milfoils and the familiar purple-spiked pickerel weed. But upon the shore and the wide flats adjacent to it grew trees whose nearest relatives—japonica, figs and a variety of aromatic

shrubs and trees—now live in the warm-temperate parts of the earth. Vines, very similar to if not identical with our modern grape, grew along with gourds, delicate climbing ferns and the less inviting cat briers. Where the bottom lands were sandy, palm leaves cast their slatted shadows on the ground.

If we could have gone back through the swampy bottoms we would have found, among others, mimosa trees and trees related to the cinnamon growing with a large variety of ferns and evergreen shrubs. Pushing farther into the drier foothills, we would have passed through woods of oak, maple, hickory and gum—woods nearly indistinguishable from the present hardwood forests of temperate North America. Higher up, pine and hemlock supplanted these familiar hardwood species, and in the highest parts of the range forests of spruce and fir predominated. That the evergreen forests were remote from the ancient lake is attested by the fact that only one seed and the tip of one twig of these species have ever been discovered in the lake deposits, though leaves of lower-zone types are found there by the hundreds. Nevertheless, forests of pine and spruce flourished; their former presence is manifested by an abundance in the lake deposits of their odd pollen grains, each of which is fitted with two bulging air sacks that aided it to float many miles from the parent tree.

The insects, too, resembled rather closely those now living. Caddice-flies, whose larvae build about their bodies little masonry houses of sand grains or well-joined "log" houses of tiny twigs, frequented the shallow water at the lake's margin, together with the more familiar dragon-flies. The wobbly-legged crane-fly was there with his diminutive cousins, the midges. Beetles, crickets and the homely grasshopper were common, but if there were butterflies and moths they have left no trace.

INDEX MAP SHOWING THE LOCATION AND APPROXIMATE EXTENT OF THE ANCIENT LAKE UINTA.

Animals coming to the lake shore must have found it a disagreeable experience, for there they met clouds of mosquitoes, black flies and gnats, and larger flies that bit savagely. Spiders and the lowly cockroach have been found, and even one mite, which, incidentally, has the distinction of being the most ancient mite in North America—America's oldest louse, if you will.

Crocodiles shared with various river turtles the sluggish parts of the streams near the lake. Land tortoises, rivaling in size the famous ones from the Galapagos Islands, plodded through the sandy lowlands. Snakes, too, there were; indeed, the most nearly perfect fossil snake ever found in the Western Hemisphere came from these lake beds. Water birds, like the loons, sandpipers and rails, must have been numerous, for impressions of feathers are common on the slabs of rock that were once mud flats bordering the lake. Of the birds themselves we know next to nothing—fossil birds are *rarae aves* indeed. Oddly enough, however, the one remarkably fine fossil bird that has been found in

these lake beds was a native of the uplands similar to our ruffed grouse.

Despite the modern aspect of the forest that encircled ancient Lake Uinta, the warm-blooded mammals that lived in it were decidedly strange. Particularly striking was the ancestor of the modern horse, for it stood no higher at the withers than an Airedale pup. Its back arched somewhat, and instead of one hoof to the foot it had four slender hoofs on each front foot and three on each hind foot. These hoofs, however, bore less of the animal's weight than did a pad at the base of the toes. The teeth of this primitive horse, unlike those of its modern descendant, were adapted to feeding upon leaves and soft, lush plants, for the West at that time was green with forest and meadow. Only through the following millions of years did it become the semi-arid region that we know to-day.

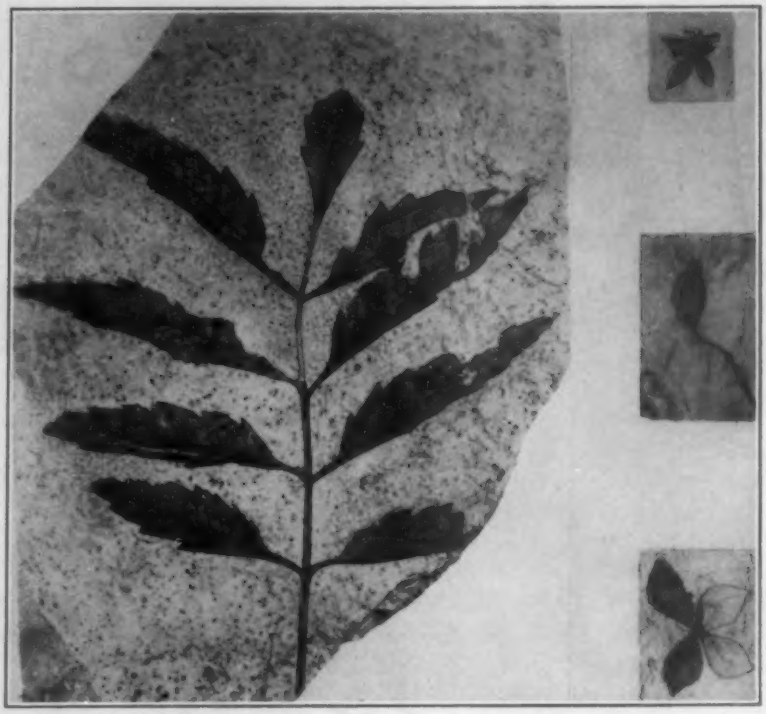
A fisherman peering down through the clear water to see what manner of fish there were among the pond weeds would not have been disappointed. Perch and other fresh-water fish inhabited the weedy bays, but they were greatly outnumbered by varieties of herring. To-day, most herring live in the sea, though a few go up rivers to spawn and a few others live in rivers. Thirty million years ago more varieties apparently went into fresh water to spawn, for those found as fossils are of two sizes—fry that had not long left the spawning ground and adults that had presumably returned from the sea to spawn. Least to be expected so far from their usual marine environment were the large sting-rays. The occurrence of so many forms that spent part of their lives in marine water implies that for a long time a perennial river ran from Lake Uinta to the sea, even though the lake was probably 600 or 800 miles inland. So great a distance from the sea would not have precluded intermigration, for salmon are known to travel more than 2,000 miles up the Yukon to spawn.

II

By the time Lake Uinta had become thus well stocked with fish it was a mature lake, for it had already been in existence more than a million years. Now as lakes grow old they, like men, acquire stores of worldly goods. So it was with Lake Uinta; as it advanced in age its waters became increasingly rich in foodstuffs. And, like a benevolent monarch, the lake gave all this increasing wealth for the good of its subjects—the varied and extensive aquatic population.

The life of a populous lake is a complex society, the members of which are interdependent. Most elemental are the microscopic plants and animals that float freely in the surface waters and derive their nourishment and energy directly from the sunlight and the dissolved salts. Upon the abundance of these minute creatures depends the very existence of other life in the community, for they are the ultimate source of food. Successively larger animals—the fairy shrimp, the water flea and the highly mechanized wheel animalcules—feed upon them and in turn are fed upon by small fish.

At this mature stage of Lake Uinta these tiny specks of life found themselves in a congenial environment, where food abounded and the temperature was most agreeable. They flourished in the midst of plenty and, late in the summer, when the water had been thoroughly warmed, literally took possession of the lake. Their numbers increased at an astounding rate; they clouded the water, then turned it a fulvous green, and finally covered it with a green scum, which the wind parted into lanes where the water might ripple again and reflect the blue of the sky. From beneath this surface stratum, filled with life, those organisms



LEAVES, FLOWERS AND A SEED

WHICH BELONGED TO DIFFERENT PLANTS THAT LIVED NEAR LAKE UINTA MANY MILLION YEARS AGO.

that had grown weary of the struggle for existence floated gently downward and sought rest in the quiet depths. So vast was the number of these weary motes that, despite their microscopic size, they bulked large in the total volume of sediment that reached the lake bottom. Indeed, these late summer epidemics gave rise each year to a distinct dark layer of organic substance. It was partly by means of these organic layers that the ancient lake recorded the passing of the years. But there would have been nothing to mark one layer off from another formed the following year or the year before, if it had not been for a different kind of sediment, which accumulated more or less continuously throughout the year.

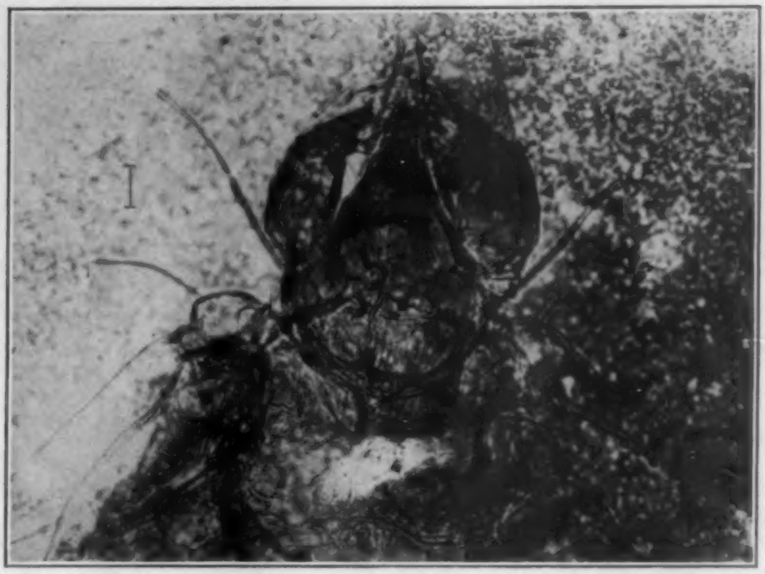
Streams brought to the lake not only fine mineral particles in suspension but also the elements of other minerals in solution. Those particles that rode in on the streams' turbulence found nothing buoyant in the quiet lake and hence settled placidly to the bottom. But the elements in solution were dispersed through the whole water body and, under the influence of the sun's warmth and the breathing of minute plants, combined with other elements to form tiny white flecks of mineral—particles of lime carbonate. These settled to the bottom as a gentle rain the year around, but most plentifully in the early summer, and formed a light-colored granular deposit that separated the dark organic layers from one another. Thus, because the dark organic layers were formed at a certain time each year and because the organic matter was then abundant enough to mask out the light-colored par-

ticles, each dark layer told off the passage of a year.

The ancient lake continued to serve as an annual calendar in this manner for thousands and thousands of years, interrupted only at long intervals by a fall of volcanic ash or by a storm of extraordinary vigor that stirred even the deep bottoms. The layered deposit was ultimately changed into rock, but the thin velvety dark bands still stand out sharply from the light-buff matrix. These layers are very thin—about 150 of them to the inch. This means that it required about 1,800 years for enough material to accumulate on the bottom of the ancient lake to make a slab of rock one foot thick. As might be expected, the varieties of rock consisting of the coarser mineral particles were built up somewhat more rapidly than this, and the finer-grained rocks, those consisting predominantly of organic substance, much more slowly. The measured rates of accumulation range from 250 to 8,200 years to the foot. By applying the rate at which each kind of sediment accumulated to the quantity of that kind of sediment throughout the body of material deposited in Lake Uinta it has been possible to estimate that the lake was in existence approximately 7,500,000 years. In this long period evolution had time to remold some of the more impressionable races of animals living in the neighborhood. For instance, ancestors of the horse family that lived at about the time Lake Uinta vanished were larger and had notably better grinding teeth than their forebears that lived just before the lake came into existence; moreover, in that interval evolution also altered somewhat the design of their toes.

In the record which the ancient lake kept year by year, we find the suggestion that the lake's volume and temperature varied in sympathy with the changing face of the sun—that is, with the number of sun-spots. Admittedly this correlation is no more than a suggestion, yet there is a fairly sound theoretical basis for believing it to be real. Foregoing all effort to explain the steps, we may present the argument in its briefest form somewhat as follows. Sun-spots are most numerous at intervals of about every 11 years, and these cycles signify changes in the amount of radiant energy that the sun emits. It has been observed that the levels of lakes which lose most of their water by evaporation and relatively little by overflow show a much closer relation to the number of sun-spots than to rainfall; in general, the fewer the sun-spots the lower the lake level. Lake Uinta at this stage had no outlet and lost much of its water by evaporation—therefore it must have had such a cyclic fluctuation of level. Next, in general the temperature of lake water rises as the lake goes down, and the higher temperature favors the growth of the minute surface-dwelling organisms and also the precipitation of particles of lime carbonate. This gives a further check on the ancient conditions, for in the deposits of Lake Uinta the layers of organic substance and lime carbonate differ in thickness from year to year and show maxima at intervals that average about 11 years. Similar cyclic variations have been observed in the thickness of annual layers formed in modern lakes. It is also a suggestive fact that the annual rings of trees that grew around Lake Uinta show even better the same 11-year cycle, just like the growth rings in modern trees.

Much longer cycles, whose average length was about 21,000 years, are also recorded in the deposits of Lake Uinta. By a somewhat more involved line of reasoning we are led to think that these observed variations in the lake deposits may be correlated with the resultant of two astronomic cycles—the change in eccentricity of the earth's orbit and the precession of the equinoxes. It remains to be seen whether these and other com-



AMERICA'S OLDEST "LOUSE"

BUT REALLY NOT A TRUE LOUSE, ONLY A RELATIVE—A PREDACEOUS MITE THAT LONG AGO FED UPON OTHERS OF HIS KIND NEAR LAKE UINTA. ITS TRUE SIZE IS SHOWN BY THE SMALL LINE AT THE LEFT WHICH IS ONE ONE-THOUSANDTH OF AN INCH LONG MAGNIFIED AS MUCH AS IS THE MITE. LIKE THE POLLEN GRAIN SHOWN IN THE SECOND PICTURE THE MITE IS EMBEDDED IN ROCK THAT HAS BEEN GROUND TO A THIN TRANSLUCENT SLICE

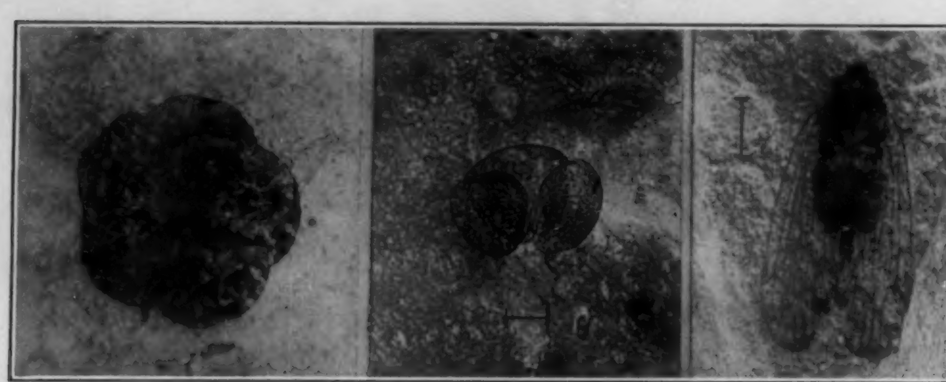
parable cyclic variations in the climate of the past can ever be used by meteorologists in their researches into secular changes of climate.

III

Lake Uinta and the surrounding countryside did not always present a picture of smiling beauty, with forests and green meadows. Instead, during the later half of its existence death and starvation laid heavy hands upon the community. From time to time pallid blankets of volcanic ash descended upon it and snuffed out the life. Animals and plants alike were smothered, and the streams were clogged with the harsh mud. Gradually, as rains washed off the slopes, the forest renewed its growth and animals again sought its shelter. But it was to no purpose, for again and yet again at long intervals the volcanoes in the neighboring mountain chains belched forth devastating clouds of pumiceous ash.

As if these recurrent disasters were not enough, the rains came less frequently: the very life-giving source of moisture began gradually but surely to dry up. Under the pitiless summer sun the more lush plants withered and finally gave up, weary of waiting for the rain. Animals wandered away in search of water.

The lake, too, suffered. For a long time it overflowed only during the cooler rainy season, but as the years passed the thirsty air drew more and more greedily from its surface until finally even at the highest stage the water could not reach the outlet. Thereafter Lake Uinta fluctuated greatly in size with the changing seasons and with every change in the weather, for a lake that has no outlet and



FLOWER, POLLEN GRAIN AND A FLY EMBEDDED IN ROCK

Left: THIS DELICATE CALYX OF AN ANCIENT FLOWER, PROBABLY RELATED TO OUR MORNING GLORY, GREW NEAR THE SHORE OF LAKE UINTA AND HAS BEEN PRESERVED IN STONE. *Center:* A PINE POLLEN GRAIN FROM THE ANCIENT LAKE UINTA. THIS SINGLE GRAIN IS GREATLY ENLARGED AND SHOWS THE TWO ROUGH-SURFACED, BULGING AIR SACS THAT ENABLED IT TO FLOAT THROUGH THE AIR FAR FROM THE PARENT TREE. THE POLLEN GRAIN IS SHOWN IN ITS MATRIX OF ROCK WHICH WAS ONCE BLACK MUD AT THE BOTTOM OF THE LAKE. THIS PHOTOMICROGRAPH WAS TAKEN BY LIGHT TRANSMITTED THROUGH THE ROCK AFTER IT HAD BEEN GROUND SO THIN AS TO BE TRANSLUCENT. BELOW THE POLLEN GRAIN IS A BAR SCALE ONE ONE-THOUSANDTH OF AN INCH LONG ENLARGED THE SAME AMOUNT AS THE POLLEN. *Right:* A TINY FLY THAT SOME THIRTY MILLION YEARS AGO DANCED ABOVE A GLEAMING MUD FLAT ONLY TO HAVE ITS WINGS AND FEET CAUGHT FAST IN THE DRYING SURFACE FILM. ITS APPROXIMATE LENGTH IS SHOWN BY A LINE AT THE LEFT.

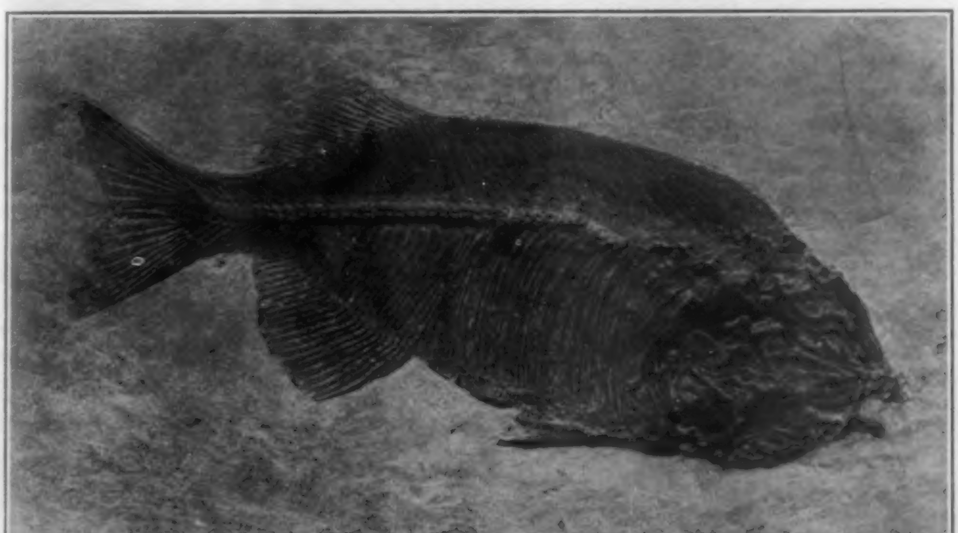
loses by evaporation as much as it receives is extremely responsive to slight variations in atmospheric conditions. As the water level varied it alternately flooded and left bare wide expanses of mud. Upon these wet mud flats scores of fish were stranded and flopped until they stiffened in the sun. Insects, dazzled by the reflected glare from the wet mud, alighted only to have their wings and feet caught in the drying surface film. When the water level rose again, perhaps only by reason of an onshore wind that pushed a thin sheet of water far up over the nearly level bottom, both fish and insects were sealed beneath a new layer of mud and so were preserved and made part of the enduring record.

As the lake retreated from its former shores it concentrated into smaller compass the community of living things that had formerly occupied a more spacious domain. The water was proportionately enriched in dissolved foodstuffs, and the density of the population increased manyfold. But conditions gradually became so congested that many forms were unable to survive. Their place, however, was immediately taken by a host of other organisms better fitted to endure the foul environment. Indeed, after thousands of years of slow dwindling Lake Uinta finally became, at its lowest ebb, a truly horrid thing—a great festering abscess breathing its stench into the shimmering summer heat. The water became bitter with salt, and the decaying organic material in the shallowest places seethed with fly maggots as they fed upon it. How abundant those maggots were is plainly told by the fact that layer after layer of them was buried, and to-day their overlapping flattened bodies make continuous paper-like layers in the thinly laminated rock that was once the lake-bottom mud.

This lowest stage in the history of Lake

Uinta indicates that the climate had changed from fairly humid to arid. The lake repeatedly deposited salt crystals along its shores and in the wet mud, but never were its waters so concentrated that continuous beds of salt were laid down. As shown by the annual layers the salt crystals formed only at intervals of about 50 years, which indicates that the water level even then rose and fell through a considerable range as the rates of supply and evaporation varied.

While Lake Uinta had no outlet and its level was prevailingly low the organisms lived in so great profusion that their remains accumulated on the bottom almost to the exclusion of anything else. But that this material endured long enough to be covered and so preserved means that it won a race with a host of bacteria and other scavenging hordes eager to destroy it. In that race, however, it suffered partial decay; the individual organisms lost their identity and melted away into a jelly-like ooze, which finally became so charged with the toxic products of decay that it became intolerable even to bacteria. When decay finally ceased, the ooze became an excellent preservative, protecting from decay the delicate plants and animals that it accidentally entombed. As the organic ooze or gel was covered by successive layers and finally by thousands of feet of sediment it was compressed and gradually hardened into a dense substance resembling hard rubber. Geologists have examined this material under the microscope by grinding small pieces so thin as to be readily translucent. These thin plates of rock, suitably mounted on glass slides, show not only finely preserved microorganisms but in addition an odd assortment of wreckage, including the eyes of tiny insects, spatulate scales from mosquitoes' wings and an abundance of pollen grains. When this hardened organic substance is heated it yields a distillate of crude oil from which may be obtained gasoline, fuel oil and related products. Hence this substance derived from the former residents of the ancient



AN ANCIENT FISH

THAT ONCE SWAM IN THE WEEDY BAYS OF THE ANCIENT LAKE UINTA. THE PHOTOGRAPH IS REDUCED—THE FISH WAS MORE THAN A FOOT LONG

lake is known as "oil shale." So plentiful were the microorganisms and so long did Lake Uinta persist that its deposits now contain locked up the equivalent of more than 70 billion barrels of crude oil waiting to supply the nation's needs when the supply of petroleum from wells becomes inadequate.

Lake Uinta was blessed in its declining years by a return to conditions more nearly like those that attended its youth and middle life. Refreshing rain heartened the forest to make another stand, and the gradually expanding lake finally purged itself by overflow. Plants of the kinds that fared badly during the protracted drought gradually spread down from the hills and resumed their former habitats. But as the streams swelled and expanded the lake in this final stage, they brought with them an unwonted burden of waste from the land—waste that had accumulated during the dry epoch. Thus it came about that the lake was commonly turbid and could not provide, as formerly, the optimum environment for an immense population.

Moreover, the prime motivating force that brought Lake Uinta into existence and that made possible its long life was beginning to grow feeble. This force had been one of great magnitude, for it was this that had warped the crust of the earth gradually downward into the great basin-shaped depression which the lake occupied. And now that this force was weakening the streams were able to bring sand and silt into the lake a little more rapidly than the downwarping could make room for it. Hence the water became more and more shallow, and stream-laid deposits pushed ever farther and farther out into the basin until there remained only a vast alluvial plain dotted with swamps and small ponds. The streams that had so long paid tribute to Lake Uinta finally overwhelmed it and brought its rule to an end.

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ARTIFICIAL PRODUCTION OF THE FABULOUS UNICORN

A MODERN INTERPRETATION OF AN ANCIENT MYTH

By DR. W. FRANKLIN DOVE
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THE horn of the unicorn, once sought after by princes and kings for its magical powers as an antidote against the poisoned cup and so valued many times its weight in gold, has had an origin in actuality and mythology which remains, even to the present time, a mystery. Hope of discovering the unicorn's actual domain was ever present so long as there remained significant stretches of either land or sea as yet unexplored. But as all regions of the world gradually came under the eye of migrating and scrutinizing man, hope of finding the unicorn gradually faded until to-day our interest in its existence has come to lie only in the strangeness of the fantasy as an idealistic concoction of the imaginative impulses of man.

The unicorn of mythology stands as the aristocrat of beasts, fearless, courageous, proud, strong and beautiful, gentle and the protector of other beasts. According to a typical description, he had the head and neck and the fine-boned, graceful legs of the horse; the beard and divided hoofs of Capridae; the tail of the oryx; and a single spike springing from the center of the forehead twisted in spirals, as is the tusk of the narwhal (*Monodon monoceros*). The horn is generally characterized as "de splendore mirifico" and was described by Ctesias, physician to the Court of Darius in Persia, as early as 398 B.C. "The base of this horn, for some two hands'-breadth above the brow, is pure white; the upper part is sharp and of a vivid crimson; and the remainder, or middle portion, is black." Fresnel says of the horn that it "springs from between the eyes. For two-thirds of its length it is of an ashen grey-colour, like the rest of the animal, but the upper third is a vivid scarlet." With his horn he purifies the streams of poison so that all animals may drink in security.

This strange one-horned creature, the history of whose imprints on the thought of man has been traced in so scholarly a manner by Odell Shepard in his "Lore of the Unicorn," back through Pliny, through Aelian, through Ctesias, beyond the Palace of Forty Pillars to legends possibly older than the Avesta and the sacred religious documents of Persia, is lost as the myth fades with man himself into the past. But elusive as he is, he provokes the statement of Shepard that he is "so credible, or rather so probable, in appearance as to make the hardiest doubter feel that if there is no such animal then an excellent opportunity was overlooked in the process of creation. He seems to fill a gap in nature."

Perhaps only a crude and literal-minded modern would lay hands on an object so endowed with sacred meanings as is the unicorn. To attempt to produce artificially the object of such a glorious myth may seem tantamount to the ridiculous, even to the profane. But a method by which the unicorn can be made may account for the "authentic" observations and descriptions of unicorns that have been reported in every past century. It is possible that some of the descriptions in literature are truly authentic reports of living unicorns, unicorns who have been produced by actual manipulation.

FOREHEAD OF NEWLY-MADE UNICORN.
THE TWO HORN BUDS HAVE BEEN TRANSPLANTED FROM THEIR ORIGINAL POSITIONS AT THE CORNERS OF THE SKULL TO THE NEW POSITION IN THE CENTER OF THE FOREHEAD BY MEANS OF PEDICLED FLAPS OF SKIN. THESE PEDICLED FLAPS ARE LEFT ATTACHED AT THE POLE IN ORDER TO ENSURE A SUPPLY OF PABULUM WHILE THE TRANSPLANTED HORN BUDS SECURE NEW VASCULAR CONNECTIONS, FUSE AND MAKE ATTACHMENT TO THE SKULL.

That the unicorn can be produced artificially has been suggested a number of times in the past. Le Vaillant, 1796, in his "Travels in Africa," describes a process of manipulating the horns of oxen. "As the horns of the young ox sprout they are trained over the forehead until the points meet. They are then manipulated so as to make them coalesce, and so shoot upwards from the middle of the forehead, like the horn of the fabled unicorn." Many centuries before Le Vaillant, Pliny had described in detail this method of twisting horns together. "And in very truth the hornes of these beasts (oxe) are of so pliable a substance and easie to be wrought, that as they grow upon their heads, even whilst the beasts are living, they may with boiling wax be bended and turned every way as a man will." Again in almost contemporary times the British Resident at the Court of Nepal is quoted by W. S. Berridge ("Marvels of the Animal World," 1921) as sending reports of uniçorned sheep in Nepal with a description of the manner in which they may be produced. "By certain maltreatment ordinary two-horned sheep are converted into a one-horned variety. The process adopted is branding with a red-hot iron the male lambs when about two or three months old on their horns when they are beginning to sprout. The wounds are treated with a mixture of oil and soot and when they heal, instead of growing at their usual places and spreading, come out as one from the middle of the skull." Shepard quotes another recent observer as writing (in 1924) that the "Dinkas,

THE TWO HORN SPIKES
GREW FROM THE CENTER OF THE HEAD OF A POTENTIAL UNICORN 4 MONTHS OLD. ONE MAY OBSERVE THAT THE OS CORNUA HAVE FUSED TOGETHER. LATER THEY FORM ONE SOLID HORN SPIKE. CONTRARY TO THE SUPPOSITION OF CUVIER AND OTHER EARLY NATURALISTS, THE YOUNG HORN SPIKES HAVE FUSED TO THE SKULL ABOVE THE FRONTAL SUTURE.

who live just south of the White Nile, not only manipulate the horns of their cattle as the Kaffirs do but use this practice as a means of marking the leaders of their herds."

Scientific scrutiny, however, has tended to pick flaws in descriptions of this process. As Berridge goes on to say, "Notwithstanding the above explanation, the majority of naturalists are inclined to doubt whether a true understanding has even yet been arrived at concerning these sheep [of Nepal], for it has been pointed out that the mere fact of searing the budding horns would not result in those appendages sprouting out at the summit of the skull instead of towards the side, and moreover, if there is any secret attending their production it has been remarkably well kept from the ever-prying eyes of zoologists. It is true that the horns of a young animal might be induced to grow together by binding them up, but in that case we should expect the bony supports to be bent aside at their bases as a result of the unnatural strain put upon them, whereas on the contrary, those of the unicorn sheep arise in quite a straight manner from the skull." Shepard points to Cuvier (1827), among others, who "speaking as a scientist says that any horn growing single would be perfectly symmetrical, and that no such horn has ever been found. A cloven-hoofed ruminant with a single horn, moreover, would be impossible, in his opinion, because its frontal bone would be divided and no horn could grow above the division."

But despite the question marks raised by zoologists, Shepard, who is nothing if not impartial in his judgment of conflicting evidence, concludes: "It seems possible, therefore, that what I may call the unicorn idea, the notion that one-horned animals exist in Nature, arose from the custom of uniting the horns of various domestic animals by a process which is still in use but still mysterious to the civilized world. Here may be the explanation of the one-horned cows and bulls that Aelian says were to be found in Ethiopia and of the unicorned cattle reported by Pliny as living in the land of the Moors. The cows with single horns bending backward and a span long seen by Vartoman at Zeila in Ethiopia may have been of this sort. The one-horned ram's head sent to Pericles by his farm-hands may have been that of the leader of their flock, and so a perfect symbol of that leadership in Athens which according to Plutarch's interpretation, they wished to prophesy for their master. Finally, the mysterious one-horned ox mentioned three times over in the Talmud as Adam's sacrifice to Jehovah may have been the most precious thing that Adam possessed, the leader of his herd of cattle."

THE UNICORN AT 15 MONTHS OF AGE. THE TWO HORN SPIKES HAVE FUSED TOGETHER TO FORM ONE MASSIVE HORN SOLIDLY ATTACHED TO THE SKULL.

THE MATURE UNICORN AT 2 YEARS OF AGE.

THE SINGLE HORN CONTINUES THE GRACEFUL CURVE OF THE BACK. THE DARK TIP OF THE HORN MAY BE RECOGNIZED AS A SPOTTING FACTOR ASSOCIATED WITH THE DEEP REDDISH-BLACK COAT COLOR PATTERN OF THE ANIMAL.

As has happened before and may happen again, investigators have been too quick to condemn what has seemed to them mere credulity. Cuvier, like all his contemporaries, was mistaken in his idea of horn structure. The writer has reported recently (*Journal of Experimental Zoology*, 69: 347–405, 1935) that the bony horn cores of ruminants (*Bos taurus* and *Capra domestica*) are not outgrowths of the skull (frontal) bones, as comparative anatomists have generally considered them to be, but are rather the products of separate ossification centers with their anlagen residing in tissues above the frontal bones, and that these anlagen or horn buds may be transplanted in whole or in part to other regions of the head where they take root and develop as true horns or parts of horns either solidly or loosely attached to the skull, according to the method of transplantation.

Since these horn-forming tissues have an integrity of their own and are self-governing (a quality not generally encountered in transplantable tissues and among the higher animals unique with horn tissues), the opportunity was available to study the ability of these tissues, when brought closely together, to fuse. In March, 1933, an operation was performed on a day-old male Ayrshire calf. The two horn buds were cut and pedicled so as to lie closely together over the frontal suture at the intersection of lines drawn from the occipital foramina and the original horn loci. The circular horn buds were trimmed flat at their point of contact so as to provide a larger fusion

surface. The transplanted tissues were also placed in direct contact with the frontal bones—the frontal periosteum having been removed in order to insure subsequent attachment of the developing os cornu (bony spike of the horn) to the frontal bones. It was expected that the two horns would fuse together into one large horn solidly attached to the skull and located between and somewhat above the eyes, as is the horn of the unicorn.

The experiment was successful. The animal, now two and a half years old, bears upon the forehead the stamp of the once fabulous unicorn. The two buds have coalesced and have formed one exceptionally large and long horn molded into the skull bones of the forehead for support. Cuvier's argument that the separation of the frontal bones at the point of origin of the horns precludes the existence of the unicorn is shown to be unfounded, since the horn spike grows not *from* the skull but *upon* the skull, first as an epiphysis, later to fuse to the frontal bones over the suture as a horn spike solidly attached to the skull. A single united sheath covers the horn spike. The horn curves slightly upward toward the tip and gracefully extends the curve of the back and neck when the animal stands at attention. Like that of the mythical unicorn described by Ctesias and Fresnel, the horn sheath is white or greyish-white at the base and is tipped with black. (Had the unicorn been a female, the horn would be tipped with red, since the color appears as a sex-limited factor in this particular breed. Both colors are mentioned in descriptions of the unicorn's horn. Light refracted from the glistening deep-red or black tip often produces a scarlet hue.) This Ayrshire bull, whose Scotch ancestors flourished under that Scotch king James I, who put the unicorn on Britain's coat of arms, is a true unicorn. True in spirit as in horn to his prototype, he is conscious of peculiar power. Although he is an animal with the hereditary potentiality for two horns, he recognizes the power of a single horn which he uses as a prow to pass under fences and barriers in his path, or as a forward thrusting bayonet in his attacks. And, to invert the beatitude, his ability to inherit the earth gives him the virtues of meekness. Consciousness of power makes him docile.

Even though the unicorn can be actually produced, one may still question any statement that the Kaffirs or the Dinkas or the men of ancient times knew how to produce unicorns by transplanting horn-forming tissues. But a statement made by Pliny in his "Naturalis Historial," Book XI, would lend credence to such a statement. In discussing the horns of oxen, Pliny says: "atque incisa nascentium in diversas partes torqueantur, ut singulis capitibus quaterna fiant." While this reference has to do with the artificial production not of unicorns but of multi-horned animals and was therefore very naturally overlooked by Shepard, nevertheless the words "incisa" (to cut) and "torqueantur" (to twist awry or to writhe) clearly denote the modern method of skin transplantation by means of pedicled flaps, *i.e.*, strips of skin so cut that they remain attached at one end for blood supply while the other end of the strip (containing, in this case, the horn bud) may be twisted or shifted to another part of the animal body as a transplantation. This reference indicates that the men of Roman times had the secret of horn bud transplantation. The same secret may have been shared by those Hebrew shepherds who, according to biblical references, made the unicorn the leader of their flocks.

According to our literature, an aristocratic nature is inherent in every unicorn. He is always the leader. Quite rightly so, and for reasons quite acceptable to behavioristic interpretation. Any animal fronted with a single horn would

learn the advantages of a single well-placed weapon and would, through experience, gain ascendance and leadership over the rest of the herd. To take a modern parallel, it is common knowledge among Argentine gauchos that the mulley animal is generally able to dominate the horned animal. The animal lacking horns usually has a well-developed frontal eminence which with the straight body weight behind it produces a more telling impact than does the side cut and slash of the horned animal. Should there be joined in one animal the mulley's potential impact with a powerfully blunt horn centrally posited, the animal would undoubtedly come to be invincible. Thus, in true modern fashion, we invert cause and effect. We can not say that the ancients made unicorns of the leaders of their herds, especially in view of the fact that such a transplantation as we have described must be effected shortly after birth when qualities of leadership are not yet discernible. But we say rather that the presence of a single horn upon the forehead of any single beast in the herd or flock gave it the incentive for leadership through a power which it learned only by experience.

The artificial production of the unicorn can serve only a very minor part in explaining a myth which has been so greatly elaborated. But such an experiment shows that if the unicorn's horn can be artificially produced by the transplantation of tissues and that if a single compound horn can arise from the forehead as a graceful and forceful weapon, then the secret may have been known to past ages—especially since an actual reference to horn tissue transplantation exists in Pliny. If even the extravagant color pattern of the horn, a white base tipped with red or black, is duplicated in the Ayrshire, then the same color scheme or one similarly extravagant could surely have been produced in ancient breeds. Finally, the experiment propitiates the modern desire to analyze behavior as the product of experience. It shows that possession of a powerful weapon alters the behavior of the animal selected to become a unicorn and indicates that the unicorn's dominant and aristocratic behavior can be brought out as a single behavior factor, unassociated with genetic origin. The dominance of a unicorned animal over the ordinary two-horned beasts of the herd is here offered as a striking instance of the dependence of behavior upon form.

In 1673 a Dr. Olfert Dapper described a unicorn observed wild in the Maine woods. "On the Canadian border there are sometimes seen animals resembling horses with cloven hoofs, rough manes, a long straight horn upon the forehead." In these same Maine woods may be seen to-day an authentic unicorn. The reader is invited to join the ranks of the many "credulous" men who have actually seen a unicorn with horn "white at the base and scarlet tipped, the leader of the herd, who can not be captured or taken alive."

SCIENCE AND THE ART OF CHEESEMAKING

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One of the finest examples of how an art may, by rule of thumb methods, develop a control of complicated biological forces is found in the practices of the cheese maker. If a large vat of milk could be divided among five cheese makers from five different nations, we could obtain five types of cheese differing radically in their appearance, physical properties and flavor.

If the cheese maker were English, he would probably make a firm-bodied, mild-flavored Cheddar; if he were from Holland he would make his part of the milk into Edam or perhaps Limburger with its high flavor and odor; an Italian would probably make a hard, dry Parmesan with small round holes, requiring two years to develop its sharp flavor; a cheese maker from Southern France would make his milk into Roquefort, a cheese with a piquant flavor and a white curd mottled with blue-green mold; and if the cheese maker came from Switzerland he would certainly convert his milk into a big Emmental or Sweitzer, puffed up with gas holes, and with a rubbery texture and a peculiar sweetish flavor.

To these characteristic cheeses could be added a long list of other cheeses, each with its own peculiar appearance and flavor. In each one the flavor is due to the growth of certain definite types of microorganisms occurring, for the most part, in the original milk. The development of the particular kind necessary to produce the flavor required for each cheese is secured by the methods of making and the curing or ripening process which follows. The cheese makers obtain this control by variation in the treatment of the curd in the vat, by varying the amount and method of salting, by the control of the temperature and humidity of the curing rooms, and to some extent by the addition of cultures of microorganisms.

These methods, even the use of cultures, were established long before Leeuwenhoek, with his crude microscope, saw for the first time the tiny organisms which became known to us as bacteria.

Before the action of these cheese organisms can be described, it will be necessary to discuss briefly the nature of the milk from which the cheese is made and the changes its constituents undergo in the making and ripening processes. Cow's milk contains about 12 per cent. of solids in solution or suspension in water. The milk sugar, the minor proteins and most of the minerals are in a true solution. About one third of the solids is fat in the form of small globules in an imperfect emulsion. The white appearance of milk is due to the casein, a complex protein maintained in a colloidal condition by various factors, among which are a combination with calcium. In other words, so long as it remains combined with calcium it exists in extremely fine particles evenly distributed throughout the fluid. When milk is acidified by the addition of an acid, the casein is freed from its combination and separates in flocks or lumps of curd. The same reaction occurs when certain types of bacteria, growing in the milk, ferment the milk sugar and produce sufficient lactic acid to precipitate the casein.

The casein may also be changed from its colloidal condition by the action of the enzyme rennin. These two reactions used separately or in combination are the basis for the manufacturing procedure

for nearly all the various types of cheese. The bacteria employed are usually the ordinary lactic streptococci of sour milk and the rennin, known commercially as rennet, is obtained by making an extract of the stomachs of young milk-fed calves.

The simplest form of cheese with which we are familiar, cottage cheese, is merely skimmed milk curdled, usually by bacterial fermentation alone but sometimes by the addition of a small amount of rennet. When the curd becomes sufficiently firm it is cut into small pieces which settle to the bottom of the vat, leaving the straw-colored fluid known as whey. This contains the unfermented milk sugar and other soluble constituents and is discarded or used to feed farm animals. The granular or flaky curd is salted and is ready for consumption without further preparation. In this simple cheese the only part played by bacteria is the preliminary fermentation of the milk which gives it its mild acid flavor.

In Neufchatel and Philadelphia Cream cheeses the bacterial action is very similar to that in cottage cheese, but another factor is introduced which materially alters the nature of the product. After the curd is separated from the whey it is subjected to pressure for several hours, which still further reduces the water content and thus restricts bacterial activity. The semi-hard cheeses, like Brie, Camembert, Roquefort, and Stilton, are pressed only enough to remove the excess water, but all the so-called hard cheeses are pressed until the curd is firmly matted together.

In Cheddar, named from the English town where it originated, there is a ripening process in which the flavor and physical properties of the cheese are materially changed. This cheese, which is the one most extensively made in this country, is started in much the same way as cottage cheese, except that it is made from whole milk and is always curdled with rennet. After the curd is cut up it is held in the warm whey with constant stirring and when the whey is withdrawn the curd is piled up on the bottom of the vat to continue the acid fermentation. When this reaches a certain point the matted curd is run through a mill which cuts it into small pieces. Salt is added and the curd is packed in hoops and held under pressure over night. The following day the pressed curd, now a firm homogeneous mass, is put away on shelves in a cool room to ripen. Much of the cheese is put on the market when only a few weeks old, but to get the real Cheddar flavor it is necessary to hold it several months. In this time a real digestion takes place and the curd, at first tough and rubbery, becomes soft and a characteristic flavor develops. The digestion is brought about, partly at least, by the enzymes in the milk or introduced with the rennet, but the peculiar flavor is the result of the slow growth of bacteria. It has not been definitely determined just which bacteria are responsible for the flavor of Cheddar cheese, but it is evident that the groups which ferment milk sugar to lactic acid are important factors. The entire process of making and curing is designed to encourage the growth of this type of bacteria.

In highly flavored cheeses of the Limburger type, a more rapid bacterial fermentation is induced by increasing the water content. In the milder flavored cheeses the ripening is in the nature of a digestion with a conversion of the insoluble casein into simpler water-soluble products, but in Limburger some of the products characteristic of putrefaction appear.

A quite different type of ripening takes place in some of the soft cheeses, of which Camembert is the best known example. The making of these cheeses begins with the usual rennet curdling and lactic fermentation, but they receive

no pressing except that the curd is drained in perforated metal hoops and is pressed into its final form by its own weight. These small cheeses, rather high in moisture, are salted by rubbing the salt into the surface of the cheese and are then placed on boards on the shelves of a cool, moist room. In a new factory it is necessary to inoculate the cheese with the essential mold, but after the factory has been in operation some time this mold infection takes place naturally. The mold that gives Camembert its flavor is a common variety, but is so characteristic of this cheese that it has been named *Penicillium camemberti*. It grows vigorously on the cheese, covering the entire surface with a thick white felt. Since molds are strictly aerobic the growth is confined to the surface, but the molds are active producers of a great variety of enzymes and these gradually penetrate the interior of the cheese. Their action is soon evident in the softening of the curd near the surface due to the digestion of the casein. This change proceeds inward until in a few weeks the entire cheese is semi-fluid and has the very characteristic Camembert flavor. This cheese ripens rapidly and is usually marketed when the softening has advanced only a short distance into the cheese.

Another type of mold-ripened cheese, in which the mold grows in the interior of the cheese, requires a longer and more complicated ripening. This type includes the English Stilton, the Italian Gorgonzola and the French Roquefort. This latter cheese is most exacting in the conditions required for its satisfactory ripening, and its development was brought about through a combination of natural conditions in Southern France. Roquefort is made from sheep's milk, not goat's milk as many suppose, and until a few years ago its manufacture was confined to the vicinity of the little town of Roquefort. In the limestone hills around this town are caves with openings at different elevations. The evaporation of water from the walls of the caves cools the air, causing rapid downward currents, until, at the lower levels, the air is cooled nearly to freezing and is saturated with moisture. Caverns have been cut into the side of the mountains intersecting the natural caves, making curing rooms through which the flow of the cold damp air is regulated to secure the required temperature and humidity. A special breed of sheep has been developed with exceptional milk production. The cheese is made in small factories, but is all brought to Roquefort to be cured. There is, as usual, a preliminary lactic fermentation, but bacterial growth in the cheese is restricted by the relatively heavy salting given the cheese in the first stages of ripening.

The Roquefort mold with which the cheese is inoculated is grown in the interior of loaves of bread held under suitable conditions so that the bread finally becomes a mass of mold in the spore stage. This is dried and ground to a powder and, as the curd is dipped into the hoops to drain, a little of the powdered mold is sprinkled over it.

Penicillium roqueforti is one of the common molds, but it has one distinguishing characteristic which adapts it to the task of ripening Roquefort cheese. Like all other molds it grows only where it can obtain air, but unlike most of them it can grow slowly when the supply of air is very limited and it is this fact that enables the cheese maker to restrict the molds in the interior of his cheese to this one species.

The close texture of the normal cheese effectively excludes air from the interior, but after the salt has been applied and the curd is sufficiently firm a large number of small holes are punched in the cheese with steel wires. These holes admit enough air to encourage the slow growth of the Roquefort mold, but not

enough to permit the development of foreign types. The atmospheric conditions essential to the proper ripening are very exacting. The temperature of the curing rooms must be not higher than 48° F. and the relative humidity must be near the saturation point. If these conditions are not constantly maintained the cheese becomes discolored and the flavor is abnormal. When all the conditions are right the Roquefort mold grows along the line of the holes, spreading into the curd and giving the cheese its mottled appearance. When the mold is sufficiently developed the cheese is wrapped in tinfoil and moved to a room held at about 40° F. This low temperature checks further growth of the mold but permits the continued action of the mold enzymes which develop the peculiar flavor characteristic of this cheese. The peppery flavor which distinguishes Roquefort from other cheese comes from the decomposition of one of the glycerides of which milk fat is composed. Sheep's milk has more of this particular glyceride than cow's milk, and for this reason sheep's milk is especially suited to the manufacture of Roquefort.

It is quite possible, however, to make Roquefort from the milk of goats, and through the efforts of the Bureau of Dairy Industry of the Department of Agriculture, Roquefort of excellent quality is made in this country from cow's milk and ripened in curing rooms in which the temperature and humidity are controlled artificially. This is only another illustration of the well-established fact that the production of a particular variety of cheese is not, as is frequently asserted, a matter of climatic conditions or peculiar herbage in the pastures but is dependent in a very large measure on the control of the growth of microorganisms. For a number of years a farmer on the Pacific Coast mou tains has been making a good Roquefort from goat's milk which he ripens in a room built in a large spring of very cold water. The water not only flows under and around the room, but a flume carries it onto the flat roof so that it pours over the walls and in its fall turns a wheel connected with a fan to circulate the air inside.

Recently caves cut into the damp sandstone bluffs along the Mississippi at St. Paul have been utilized to cure Roquefort made from cow's milk, and now an abandoned shaft in a Pennsylvania coal mine is, after a coat of whitewash and the installation of partitions and dampers, making an excellent Roquefort curing room. The air forced through the wet shafts of the mine by the mine fan maintains this room at exactly 48° F. with a humidity near the saturation point.

If we go into the mountain valleys of Switzerland, we find a cheese with an even more complicated biological process and requiring more delicate control of conditions. A normal Swiss cheese weighs from 160 to 200 pounds and is made in a large copper kettle either suspended over a fire or provided with a steam jacket so that the milk may be warmed quickly and the temperature controlled throughout the making process.

To insure a good Swiss cheese it is necessary to bring about a succession of bacterial fermentations produced by different kinds of bacteria, each one taking up its work at the proper stage and supplementing what has been done by its predecessors.

The Swiss cheese makers had learned how to bring this about long before a bacteriological explanation was possible, and it is only in recent years that the bacteriological history has been worked out in detail. In this cheese the lactic streptococci, which are so important in most varieties, play only a minor rôle. Before the cheese is made a certain amount of growth of these bacteria should have taken place in the milk to

bring it to a certain degree of "ripeness," but when the rennet curd has been formed in the kettle and cut up into small pieces the temperature is maintained so high that the ordinary lactic streptococci can not grow. While in making Cheddar cheese the curd is allowed to mat on the bottom of the vat, the Swiss cheese curd is vigorously stirred until each particle becomes a firm granule not much larger than a grain of wheat. At just the right stage, which the cheese maker determines by the "feel" of the curd, the entire mass is scooped out of the kettle and put in a wooden hoop to press. In the meantime, the first of the essential bacteria have begun to develop. These are a group of lactic acid cocci which grow rapidly at the relatively high temperature of the whey in the kettle and of the curd in the press. These bacteria are actively engaged in fermenting the milk sugar to lactic acid, but the temperature of the curd falls in three or four hours below the limits of their activity.

There are only three or four varieties of bacteria working with the cheese maker, but no one could say how many there are which work against him. It is certain, however, that the one which gives him the most trouble is a group of gas-forming bacteria, always present in the milk and always ready when conditions come right to convert the milk sugar into acid and gas. The gas-formers are very detrimental to the cheese, and if they are not held in check may fill the curd so full of gas bubbles that it is like a loaf of fresh bread. The temperature in the kettle and in the curd for a few hours after it is dipped into the press is above their growth limit, but as the temperature slowly falls there is a critical time when they are able to again begin multiplication and the formation of gas.

The skilful cheese maker forestalls this contingency by making sure that the curd is well populated with another type of bacteria capable of combatting the gas formers. These are the lactic bacilli, which are even more active acid-formers than the lactic streptococci and continue their activity when the reaction of the curd has become so acid that other bacteria are inhibited. They also grow at higher temperatures than most of the gas formers and if they are in condition to become active promptly when the temperature falls to their growth limit they will be able to take up the work where the thermophilic cocci stopped and form acid enough to check the gas formers before they have done any harm. In 18 or 20 hours the lactose is nearly all converted to lactic acid and the curd is so acid that the danger from these gas formers is past.

The cheese is held a few days in a cool room, part of the time in a salt bath, and then is transferred to the warm room at 70 to 75° F., where a new group of bacteria takes up the work of the ripening or curing. The lactates formed from the lactose are fermented by these bacteria with the formation of propionic acid, a fermentation which gives Swiss cheese its peculiar sweetish flavor. Incidentally, carbon dioxide gas is produced. In Cheddar the open texture of the cheese allows the gases formed in the ripening to escape, but treatment of the curd in the making process gives the Swiss cheese a rubbery texture which holds the gas in bubbles expanding slowly to form the "eyes," the chief characteristic of Swiss cheese. If the fermentation has progressed properly the eyes are uniform in size and appearance, evenly distributed, and neither too large nor too small. If the eyes are right, it is almost certain that the flavor will be satisfactory. Consequently, Swiss cheeses are graded and the price determined by the appearance of the eyes.

When the eye formation has progressed to the proper stage, as indicated

by the swelling of the cheese, the cheeses are moved to a cool room for the completion of the ripening. The flavor is usually considered at its best when the cheese is five or six months old, but much of the domestic cheese is put on the market before this time has elapsed. The Swiss cheese maker must be very sure of the quality of his milk, not only in respect to the bacteria which it may contain, but also its physical properties when acted on by rennet and acid. Some milks form a tough curd that is not sufficiently elastic to permit the desired eye formation, while other milks curdle very slowly when the rennet is added, forming curd which never gets the rubbery texture required of a good cheese.

Milk which has too much fat gives the cheese a tendency to crack when it is expanded by the growth of the eyes, but if the cheese does not contain sufficient fat the curd is tough and dry. If the cheese maker is able to steer between these rocks he still has the undesirable bacteria to guard against.

The primitive cheese maker obtained his rennet extract by soaking a dried calf's stomach in whey. After standing over night in a warm place this whey contained not only the rennin extracted from the stomach, but a vigorous culture of the acid-forming bacteria from the previous day's cheese. This is a somewhat haphazard way of insuring the presence of the right kinds of bacteria, and in the up-to-date factories the dried rennets have been replaced by a commercial rennet extract, and pure cultures of bacteria from a laboratory take the place of the chance inoculation. Three cultures are now commonly used; the thermophilic streptococcus, which begins the acid fermentation in the curd; the lactobacillus, which carries it to completion; and the propionic bacteria, which are responsible for the flavor and at least part of the eye formation.

The latter culture grows slowly, but retains its vitality for a long time and can be furnished the cheese maker as bottled liquid cultures or in a dried preparation. It is only necessary to add a small amount to each kettle of milk.

The streptococci and the lactobacilli, on the other hand, must be grown in the factory so that they can be added to the milk at just the right stage of development. A bacterial culture, inoculated into fresh culture media, passes through three distinct stages each of which has its effect on the physiological properties of the cells making up the culture. There is at first the lag period in which the cells are increasing in size but not in number; then comes a period of rapid multiplication followed by a cessation of growth and a slow decline.

To insure the presence in the cheese of a large number of bacteria in condition to begin active growth when the temperature conditions permit, the cultures must be added to the cheese milk at just the right stage of growth. This requires accurate control of the temperature at which the cultures are grown and careful adjustment of the amount of inoculation and time of incubation.

The up-to-date cheese maker must provide himself with an incubator, sterilizer, flasks, thermometers and other equipment of a bacteriological laboratory and maintain his cultures in an active condition by daily transfers in sterile milk or whey.

It is not enough merely to add the cultures to the milk. The amount of culture must be carefully adjusted so that the acid development will, on the one hand, be fast enough to check the gas-forming bacteria and on the other not so rapid that the curd becomes dry and tough. The cheese maker can determine fairly well by various signs which he has learned to recognize if the acidity has developed properly, but in laboratory controlled manufacture the progress of the fermentation is measured by determining the hydrogen ion concentration

at intervals. If, three hours after the curd is put in the hoops to press, the acidity may be expressed by a pH of about 6.00, the thermophilic streptococci have begun the fermentation of the sugar. If five hours later the acidity has increased so that the pH is about 5.50, it may be assumed that the lactobacilli have taken up the work at the proper time. The next morning the pH should be between 5.00 and 5.20 and the milk sugar very nearly all fermented. The bacteriological balance in the cheese is so delicate that, if at this stage the cheese maker should change his mind and decide to make a Gruyere instead of a Swiss cheese, he could, by slightly altering the method of salting and curing room temperature, completely change the subsequent bacterial development. The gas formation is so suppressed that the eyes are small and round. The surface of the cheese is covered with a bacterial growth that causes a peculiar ripening proceeding from the surface inward and forming so much ammonia that the atmosphere of a Gruyere curing room is decidedly irritating to the eyes.

Any one who has attempted to follow the intricate balance which must be maintained to obtain a Swiss cheese of good quality, can not fail to have the greatest admiration for the men who learned to control this process without the least knowledge of the biological factors which were the basis of their methods.

A very large quantity of Swiss cheese is made in this country but almost entirely by Swiss people, many of them born in Switzerland and trained in the shadow of the Alps. They have retained their language and customs, and no convention of Swiss cheese makers is complete without its yodelers and wrestling and gymnastic contests.

Only a man of more than ordinary physique and constitution can withstand the hard work and long hours required in the operation of a Swiss cheese factory. His work begins in the early morning hours and, if the usual custom of making cheese from the evening milk is followed, it will extend well into the night. Between the actual making periods there are long rows of 175-pound cheeses to be taken from shelves, turned over and put back. It is related that one cheese maker, going through this routine, still had an unoccupied hour or two in the middle of the day, some of which he spent in working with a 50-pound dumb bell "to keep himself in good condition."

Swiss cheese making is scattered through several states, but by far the greater part is made in two restricted sections. One of these is in Ohio, but in southern Wisconsin there is a much larger district, with many well-constructed factories, some of them larger than any in Switzerland. Much of the cheese made in these factories is of excellent quality, but in general it suffers by comparison with the imported cheese because, while all grades made by the American factories go onto the market, Switzerland sends only carefully selected cheese to this country. It also suffers from the recently developed practice of grinding the poorer grades of cheese, melting the mixture and running it into molds to form a convenient package for marketing. Restaurant attendants have acquired the habit of referring to this product, which has lost the characteristics of the original cheese, as "domestic," while cheese with eyes is called "imported."

THE MALTHUSIAN PRINCIPLE IN NATURE

By W. L. McATEE

THE BIOLOGICAL SURVEY, U. S. DEPARTMENT OF AGRICULTURE

Introduction

The essay on the "Principle of Population" by T. R. Malthus ran through six editions (1798–1826) during the author's lifetime. In the first edition he "put forward the view that population, when unchecked, increases in a geometrical ratio, while subsistence increases in only an arithmetical ratio, and Malthus asserts as a fact that population always increases up to the limits of the means of subsistence."[1] In the second edition, "while maintaining his 'principle' of population—the universal tendency of population to outrun the means of subsistence—he allowed the question of the mathematical ratios to fall rather into the background."[2]

The Malthusian principle appears therefore to be an alleged "universal tendency of population to outrun the means of subsistence." It was used as a basis for arguments as to a struggle for existence resulting in natural selection and survival of the fittest by Darwin, who like various other authors did not sufficiently appreciate the vast difference between a theoretical potentiality and the actual realization thereof. As a matter of fact, it is seldom even in the very unnatural case of mankind, and rarer still in nature, that populations actually outrun the means of subsistence.

Geometric Increase

Referring to the human race, Malthus said, "population, when unchecked, goes on doubling itself every twenty-five years, or increases in a geometrical ratio," but "the means of subsistence under circumstances the most favorable to human industry, could not possibly be made to increase faster than in an arithmetical ratio."[3] This conclusion seems to have been reached by Malthus on the grounds of space for crops being limited, for he says: "Man is necessarily confined in room. When acre has been added to acre till all the fertile land is occupied, the yearly increase of food must depend upon the melioration of the land already in possession."[4] As much weight should be attached to the thought in the first, as to that in the second, of the sentences quoted. Space for mankind itself is limited and the human population can not increase indefinitely, because density becomes a factor in checking population growth, a point that will be more fully discussed later.

Modern studies of population growth have shown that it does not continue at a geometric rate (Pearl, Yule), but in each period of approximately uniform conditions, invariably levels off so that there comes to be no increase at all. In the words of Yule, who characterizes Malthusian speculations as nightmares, "growth does not follow the geometric law, but . . . the percentage rate of increase tends steadily to fall as numbers enlarge."[5] Since this development is at present taking place in our own and other countries where there is an excess of food, it is evidently not the result of

[1] Claude W. Guillebaud, Encyclopedia Britannica, 14th Ed., 14, p. 744, 1929.

[2] *Ibid.*, p. 745.

[3] T. R. Malthus, "An Essay on the Principle of Population, or, A View of its Past and Present Effects on Human Happiness; with an Inquiry into our Prospects Respecting the Future Removal or Mitigation of the Evils Which it Occasions," Fifth Ed., Vol. 1, pp. 9 and 14, 1817.

[4] *Ibid.*, p. 9.

[5] G. Udny Yule, *Jour. Roy. Statistical Soc.*, 88, p. 22, January, 1925.

a shortage in subsistence. The occurrence, moreover, negatives another of Malthus's cardinal propositions, namely, that "population always increases where the means of subsistence increase."[6]

That increase in food may have the same sort of ratio as that of population is shown by the fact that it has more than kept pace in the century since Malthus's time, during most of which a very rapid growth in population has occurred. As to the reason, the Secretary of Agriculture of the United States has recently said, "When it is possible for the farmers of a nation to increase production 50 per cent. while crop acreage is increasing only 25 per cent. we know that science has been at work. That is exactly what has happened in the United States in the past 30 years."[7] Referring to a definite part of this period, Dr. O. E. Baker says, "Between 1921 and 1926 agricultural production increased about 27 per cent. whereas population increased 9 per cent."[8]

The assumption that subsistence factors dominate population growth appears antiquated anyway in these days, when, although populations generally seem coming to a standstill, we are at the same time seeking agreement by international conferences to decrease food production, and nations are warning, forcing or even paying farmers to reduce crop acreages.

From a theoretical point of view, moreover, Malthus's assertion that population increases in a geometrical, food in only an arithmetical, ratio is unsatisfactory, as all man's food consists of organisms, every one of which has the same potentiality for geometrical increase as himself and most of them at a much higher rate. The extent to which the respective tendencies have been permitted realization is the effective factor. No domestic animal, for instance, is permitted to breed unrestrictedly. Man regulates such increase, and in some fashion he has always regulated his own increase. The problem of the growth of human population is an artificial rather than a natural one and even if the Malthusian principles held good for it, there would be no warrant for extending them to populations of organisms in nature, uncontrolled and unaffected by man.

Malthus stated his principle in a general form to the effect that there is a "constant tendency in all animated life to increase beyond the nourishment prepared for it,"[9] and he elaborated upon this idea as follows:

> Through the animal and vegetable kingdoms Nature has scattered the seeds of life abroad with the most profuse and liberal hand; but has been comparatively sparing in the room and nourishment necessary to rear them. The germs of existence contained in this earth, if they could freely develop themselves, would fill millions of worlds in the course of a few thousand years. Necessity, that imperious, all-pervading law of nature, restrains them within the prescribed bounds. The race of plants and the race of animals shrink under this great restrictive law; and man can not by any efforts of reason escape from it. . . .
>
> In plants and irrational animals, the view of the subject is simple. They are all impelled by a powerful instinct to the increase of their species; and this instinct is interrupted by no doubts about providing for their offspring. Wherever, therefore, there is liberty, the power of increase is exerted; and the superabundant effects are repressed afterwards by want of room and nourishment.[10]

What the Malthusian argument chiefly neglects is that "nourishment" in almost all cases is other organisms, each having the same sort of capacity for increase as the nourished. Consumer and producer are on the same, not on different, bases. Self-limiting factors also are not given proper weight.

[6] *Loc. cit.*, p. 34.

[7] H. A. Wallace, *U. S. Dept. Agr. Official Record*, 12: 19, p. 73, May 13, 1933.

[8] O. E. Baker, *U. S. Dept. Agr.*, *Extension Circ.* 168 (mimeographed), p. 12, July, 1931.

[9] *Loc. cit.*, pp. 2–3.

[10] *Ibid.*, pp. 3–4.

Subsistence Effects

That "Population is necessarily limited by the means of subsistence"[11] is one of the chief Malthusian pronouncements. Just what the author intended to convey by the expression "means of subsistence" is not entirely clear, but if it be not taken as a synonym of food, the formula quoted becomes a pointless truism, "Population is necessarily limited by all things essential to it." If, as ordinarily done, we take the statement to mean that population is limited by the food supply, it is evident at once that an alternative mode of expression would be more truthful, namely, that population in some cases may be, or in the last extremity, must be, limited by food supply. While the quantity of food available undeniably sets an ultimate limit to increase in population, to assume that it is a factor constantly functioning in the regulation of populations is quite another matter.

The lavishness of nature gives us opportunities of observing in many cases that means of subsistence is not the factor limiting populations. Provision for reproduction of organisms characteristically is on a profuse scale. In the plant kingdom flowers as a rule are superabundant; unconsumed millions of them wither away, and their pollen, a nutritious food, is largely wasted, some of it in showers that color the landscape. There are some flower-eating creatures, and fairly numerous pollen and nectar feeders, but their populations would be much greater were the food supply the effective limiting factor upon them.

A similar situation prevails with respect to the eggs of some animals, those of pelagic breeding fishes, for instance, which are shed in countless millions and often cast upon shore in windrows where the great bulk of them disintegrate uneaten. The supply would set no humble limit upon the numbers of egg-eaters, yet the latter are limited after the fashion of organisms in general.

Leaves are pasturage for an immense number of organisms; nevertheless, the rule is for the trees to retain their foliage essentially unimpaired until it has fulfilled its function and falls, another increment to the forest duff in which form, furthermore, it is years in being utilized for nourishment, either by animals or plants. The prevailing rule—luxuriant greenery all about us—certainly indicates that it is not the supply of foliage that sets the limits for leaf-feeding organisms.

The means of subsistence of some organisms may be compared with an ever-bubbling spring, the flow of which is never consumed. Such a food is plant sap; it is never exhausted except extremely locally, yet the sap-feeders (most of the great order Rhynchota, for instance) maintain their populations evidently in accordance with the same principles that affect organisms utilizing nourishment apparently much more limited in abundance.

Comparable instances are those of larvae, such as tent caterpillars, which feed on newly expanding leaves. Often they seem to gnaw these down as fast as they grow, but as soon as the caterpillars complete their growth, out spring the leaves and clothe the tree with its normal foliage. In this case again subsistence evidently has not limited population.

Plant galls to which nourishment keeps circulating so long as their inhabitants are developing constitute a similar example. Some insects and other organisms are actually domiciled in a mass of their food, which in many cases is almost infinitely beyond their capacity to consume. The wood-boring larvae (Cerambycidae, Cossidae, Sesiidae, etc.) are excellent illustrations. The Prionines, Xylotrechines, Xylophagids, Clusiids, etc., have a similar relation to fallen

[11] *Ibid.*, p. 33.

trees, and generations of adults emerge year after year from the same log—from an enormous food mass, the presence of which evidently does not cause their populations to increase up to the subsistence limit.

Among organisms dwelling within their food, a great variety of internal parasites must not be forgotten. Though they live in the midst of plenty, they maintain, as a rule, average numbers, but assuredly not those which would be possible were available subsistence the controlling limitation upon their populations.

These instances may be considered as meager or atypical or even as capriciously selected. Such objections need not be replied to in detail, however, for the naturalist observes, in almost any direction he may turn, an apparent abundance rather than a scarcity of food supplies. The writer long ago showed that invertebrates and seeds could have such numbers even in winter as 1,216,880 animals and 2,107,810 fruits and seeds per acre, respectively, on the forest floor, and 13,654,710 animals, and 33,822,745 fruits and seeds per acre, respectively, in fields near Washington, D. C.[12] The average population of birds in this region is not more than from 2 to 3 per acre, a number that evidently is not fixed by the food supply. A similar case is presented in data relative to Oneida Lake, New York. F. C. Baker[13] estimates the number of herbivorous animals of the lake at 7,743 millions of individuals, and the carnivores at 23 millions. The latter population is only about three tenths of one per cent. as numerous as the former and its food supply therefore is enormously superabundant.

The theme could be elaborated at length, but that seems unnecessary. If populations were in reality limited as a rule by the means of subsistence, we would see on all sides starvation of populations and devastation of environments. The fact is we rarely see either. This statement is made with full consciousness of occasional local exhausting of food supplies by rabbits, hares and other animals.

P. P. Calvert noted in 1900 that:

> In spite of the continuous need of food by all animals . . . it is extremely difficult to point out cases where famine alone operates, under natural conditions, to increase the severity of the struggle for existence.[14]

In a translation dated 1904, August Weismann is recorded as saying that even "a low rate of multiplication is not in itself sufficient to prevent the excessive increase of any species, nor is the quantity of the relevant food-supply. Whether this be very large or very small, we see that in reality it is never entirely used up, that, as a matter of fact, a much greater quantity is always left over than has been consumed. If increase depended only on food-supply, there would, for instance, be food enough in their tropical home for many thousand times more elephants than actually occur; and among ourselves the cockchafers might appear in much greater numbers than they do even in the worst cockchafer year, for all the leaves of all the trees are never eaten up; a great many leaves and a great many trees are left untouched even in the years when the voracious insects are the most numerous. Nor do the rose-aphides, notwithstanding their enormously rapid multiplication, ever destroy all the young shoots of a rose-bush, or all the rose-bushes of a garden, or of the whole area in which roses grow."[15]

[12] W. L. McAtee, *Science*, 26: 666, 447–449. October 4, 1907.

[13] F. C. Baker, N. Y. *State Coll. Forestry. Circ.* 21, p. 30, August, 1918.

[14] P. P. Calvert, *The Veterinarian*, 73: 875, p. 594, November, 1900.

[15] August Weismann, "The Evolution Theory." Translated with the author's cooperation by J. Arthur Thomson and Margaret R. Thomson. Vol. I, p. 45, 1904.

Two years later Frederic Merrifield, in the president's address before the Entomological Society of London, said:

> On the whole I think it would be difficult to show that any species of vegetable-feeding insect was ever wiped out or turned from a common kind to a rare one as a consequence merely of its food plant having been all—or nearly all—eaten down by itself or its congeners; so that whatever may be the cause of the remarkable numerical constancy we find in individuals of different species, this persistence can not be sufficiently accounted for by the relation between the food supply and its insect consumers.[16]

W. R. Thompson, more recently, has written that "any biologist who has observed the work of plant-feeding species in Nature will admit that obvious signs of severe injury are uncommon, while the total destruction of plants is extremely rare."[17]

In 1933 A. J. Nicholson summed the matter up in a way that naturalists must regard as fair, when he said, "It is generally recognized that in nature few animals die as a direct result of starvation."[18]

We must therefore conclude that the Malthusian principles, "population is necessarily limited by the means of subsistence" and "population always increases where the means of subsistence increase," do not normally function in nature.

SPACE EFFECTS

Malthus would have been better advised had he insisted more on the element of room which he mentions both in connection with man and with lower organisms, but he chose to emphasize subsistence.

To introduce the evidence as to space effects we quote from Dr. Raymond Pearl:

> It has long been known that the degree of crowding of organisms in a given space, or density of the population, has an influence upon various vital processes of the individuals composing the population. In the matter of growth of the individual animal Semper[19] long ago showed that volume of water apart from food and other conditions has an influence upon the rate. This subject has again been studied recently by Bilski.[20] Farr[21] maintained that there is in human populations under certain conditions a definite relation between density of population and the death rate. This old work of Farr's has recently been taken up again and confirmed by Brownlee[22] for certain portions of the population of England and Wales.[23]

Dr. Pearl's own experimental work was with the pomace fly (Drosophila) and in describing the results where the same number of flies were used as foundation stock in containers of different capacity, he says:

> The maximum population is nearly five times as large, instead of twice, in the pint bottle as it is in the half-pint . . . while (the pint bottle) has a little more than twice as much free air space as the former, it has nothing approaching five times as much. If the surface area of the food, namely the area on which the adult flies can find yeast to eat, be considered . . . the case is obviously worse. The ratio of the larger to the smaller universe is not even so great as two.[24]

In other words, the growth of population was proportional to the volume of the container, not to that of the food.

[16] Frederic Merrifield, The President's Address, *Proc. Ent. Soc. Lond.*, 1906, pp. cxix–cxxx (publ. with *Trans. Ent. Soc. London* for 1906), 1906–1907.

[17] W. R. Thompson, *Ann. Applied Biol.*, 17: 2, p. 315, May, 1930.

[18] A. J. Nicholson, *Jour. Animal Ecol.*, 2: 1, p. 166, May, 1933.

[19] K. Semper, "The Natural Conditions of Existence as they Affect Animal Life," Fourth Ed. 1890.

[20] F. Bilski, *Pfluger's Arch. f. d. Gesamte Physiologie des Menschen u. d. Tiere*, 188: 4–6, 254–272, June, 1921.

[21] William Farr, Fifth Ann. Rep. Reg.-Gen. of Births, Deaths, and Marriages in England (2nd ed.), pp. 406–435, 1843; Suppl. 35th Ann. Rep. Reg.-Gen. of Births, Deaths, and Marriages in England (2nd ed.), XXIII–XXV, 1875.

[22] J. Brownlee, *Jour. Hyg.*, 15: 11–35, 1915; *Jour. Roy. Stat. Soc.*, 82: 1, 34–65, January, 1915; *ibid.*, 83: 2, 280–283, March, 1920.

[23] Raymond Pearl, "The Biology of Population Growth," p. 131, 1925.

[24] *Ibid.*, pp. 41–42.

In experiments with varying numbers of foundation stock in identical environments, he found that the production of imagos per mated female per day varied from 21.4 in bottles containing only one pair of the flies to 0.33 in those containing 50 pairs. He notes accordingly that, "there is a profound and regular change in the rate of reproduction of *Drosophila,* under the conditions of these experiments, with increasing density of population. The rate of reproduction per mated female declines as density of population increases, at first extremely rapidly, and then more and more slowly at higher densities."[25]

Generalizing the data available to him, Dr. Pearl concludes,

that rate of reproduction or fertility is negatively correlated with density of population, in (a) experimental populations of flies, (b) experimental populations of hens, and (c) urban populations of human beings. This array of evidence indicates that in the direct and indirect biological effects of density of population upon reproduction exists one *vera causa* for the damping off of the growth of population as the upper limit of the logistic curve is approached.[26]

Another investigator, Morris H. Harnly, who also used Drosophila as a subject, sums up his findings in these words:

Increase in the food volume (depth) with a constant area (24 sq. cm.) followed the law of diminishing returns—. . . until the optimum was reached (at 22 to 26 mm). Beyond that point additional food had no effect upon the total population supportable on a given area.[27]

The effects of crowding on reproductive rate have been noted also by various other authors. R. E. Lloyd, for instance, wrote in 1912:

The fertility of captive animals often depends on space. Wild rats will seldom produce young when confined in small cages, but breed readily enough in a large enclosure. A pair of pigeons will produce no young in a small cage. The same pair, however, if removed to a large cage will breed, but the group of their descendants will cease to expand as soon as the cage becomes crowded, the numerical size of the group depending on the capacity of the enclosure.[28]

"In the case of plants" also, Yule notes that "there is a marked effect of density. Wheat and barley plants planted at close spacing do not merely show a reduction in yield of grain which might be attributed to starvation; the actual number of ovules formed on the first tiller is reduced, an effect which can be seen within the first month of the life of the plant."[29]

Oscar W. Richards states regarding experiments he conducted with yeast that while definite cycles of growth were demonstrated "the food supply was not a limiting factor."[30]

Referring to his own experiments on yeast and those of Terao on a water flea G. F. Gause says, "In these experiments there was one point in common . . . the equilibrium was not due to any deficiency of food" . . . and of further experiments of his own on *Drosophila,* "the sharp decrease of the density of saturating population at 30° temperature was not connected with any lack of food."[31]

In 1927 Everett Clark Myers reviewed experimental work on the effects of density upon protozoan populations and reported on extensive experiments of his own with *Paramecium caudatum.* The conclusions pertinent to the present discussion are as follows:

Decreasing the volume of fluid . . . decreases the total population produced. The number present at the maximum is nearly proportional to the volume of the fluid employed. . . . As the density of population in a given volume of culture fluid increases, the rate of reproduction

[25] *Ibid.*, p. 136.

[26] *Ibid.*, p. 209.

[27] Morris H. Harnly, *Jour. Exp. Zool.*, 53: 2, p. 167, May, 1929.

[28] R. E. Lloyd, "The Growth of Groups in the Animal Kingdom," p. 30, 1912.

[29] *Loc. cit.*, pp. 34, 35.

[30] Oscar W. Richards, *Ann. Bot.*, 42: 165, p. 280, January, 1928.

[31] G. F. Gause, *Quart. Rev. Biol.*, 7: 1, p. 44, March, 1932.

falls off, finally ceasing. . . . In all cases the greater the number of individuals per volume, the less the reproductive power.[32]

Royal N. Chapman in breeding flour beetles (*Tribolium confusum*) found that the population increased up to a certain point, when the immature stages were eaten by the adults to an extent which held the numbers about constant. He also found that "the increase of a population is proportional to the total size of the environment."[33]

Writing of another grain-eating insect with which he experimented, D. Stewart Maclagan wrote in 1932:

> Perhaps the most significant fact resulting from this analysis of the "space factor" is that the female *Calandra* will not lay the maximum number of eggs produced under the conditions of these experiments until the number of grains available are at least eight times that actually utilized. This does not occur until there are 400 grains to every female weevil, when the number of males and females in the population are equal. Even at the "optimum" in regard to space utilization for purposes of oviposition, nothing would induce the female weevil to utilize more than approximately 50 per cent. of the total available number of grains.[34]

Summarizing the findings of himself and others, Maclagan says: "Analysis of existing data combined with laboratory experimentation upon different insects, demonstrate the great definity of operation of the 'space factor,' also, the existence of an 'optimum' density for rate of reproduction,"[35] and concludes: "It would appear . . . that natural populations automatically check their own increase by virtue of this density effect, and that the organism itself imposes the ultimate limit to its own abundance when all other factors (biotic and physical) normally inhibiting population increase, have failed."[36]

It is fully evident that there is a space effect of importance in controlling certain plant and invertebrate populations. The phenomenon in the case of vertebrates has been the subject of ordinary observation by generations of naturalists, and has more recently been cast in the form of a territorial hypothesis. It has been most accurately observed, perhaps, in the case of game birds, and Leopold in his book on Game Management writes, "it may be said with reasonable assurance that within the main range of the bobwhite, a density limit of approximately one bird per acre exists and probably always has existed."[37] Moreover, the density of population apparently can not be increased by addition of species of similar environmental requirements, and upon this point Leopold concludes "that mixed stands are to a large degree subject to the same combined saturation point as would hold for pure stands of the constituent species."[38]

In attempting to explain the situation, Leopold uses language very reminiscent of that of Maclagan on insects.

> If external or environmental forces alone determined maximum density, the maxima occurring in a large number of samples in one state . . . might be expected to run much higher or lower than in another. The fact that they do *not run* higher or lower in bobwhite on its main range is evidence that some *internal* force or property, which is not subject to large variation as between regions, is also operative, and sets the upper limits beyond which wild populations do not increase.[39]

In extended studies of the house wren, Kendeigh found that "the number of broods per female per season tends to

[32] Everett Clark Myers, *Jour. Exp. Biol.*, 49: 1, pp. 40, 41, 42, October, 1925.

[33] Royal N. Chapman, *Ecology*, 9: 2, p. 120, April, 1928.

[34] D. Stewart Maclagan, *Proc. Roy. Soc. (Lond.)*, Ser. B, III (B773), p. 445, October, 1932.

[35] *Ibid.*, p. 454.

[36] *Ibid.*, p. 452.

[37] Aldo Leopold, "Game Management," pp. 52–53, 1933.

[38] *Ibid.*, p. 84.

[39] *Ibid.*, p. 54.

vary inversely with the total population."[40] On a certain tract in Ohio, he found that when the number of nests was 7 the broods per female was 1.8; when the number of nests was 14 the broods fell to 1.2 per female.

As a result of study of the great crested grebe in England, Venables and Lack conclude that territorial behavior in that species is not correlated with food supply, and cite other statements of the same principle which they deem general.[41]

A specific illustration of the principle may be cited from Harrisson and Buchan's report on the St. Kilda wren.[42] They state that:

> In one pair especially studied the territory was found to be composed of a number of sub-territories, small areas in which food was taken. These food territories constituted only 2.6 per cent. of the whole territory, and 85 per cent. of the food of the young was obtained in 1 per cent. of the whole.

Despite clear evidence to the contrary in some of the instances, certain laboratory workers have been inclined to consider the "space effect" at bottom a "subsistence effect." While this impression may have been favored by the results in some cases of artificial environments, the fact that "space effects" are known also in a state of nature where food normally is in excess points to the conclusion that "space effects" are a real entity, the course of which may sometimes seem to parallel "subsistence effects," but which is quite independent and may produce results in no way correlated with subsistence. This independence is further shown by the unfavorable results from undercrowding. Allee summarizes knowledge on this point as follows:

> It is easy to demonstrate that overcrowding lessens the rate of growth of organisms. More recently evidence has been accumulating that undercrowding frequently has the same effect. Evidence is presented on this point in such widely different animals as mealworms, fishes, and mice. Similarly, with population growth the harmful effects of undercrowding have recently been found for protozoans, crustaceans, and beetles, as well as the ill effects of overcrowding.[43]

Populations Tend to be Self-limited

In introducing this subject we take advantage of remarks made by experimenters with the flour beetle, one of the organisms cited in the preceding section as manifesting the "space effect," at least in microcosms.

Chapman and Whang in a paper from which convenient references to nine other articles on the general subject may be obtained, state that "population systems of flour beetles produce a resistance to their own potential rate of increase."[44]

T. G. Holdaway, who worked with the same insect, comments on self-limitation of its populations, and extends the principle to natural populations. He says, in part:

> Actually the theoretical geometric growth of the population does not take place. If it did the population would increase so rapidly and reach so high a concentration in a very short time that no food would remain and the population would perish . . . in nature the maximum rate of increase does not continue beyond a short period of time. There is generally some provision whereby the numbers are kept down and a more optimum concentration maintained, so that the food supply does not constitute a limit to the survival of the species . . . the important point is that self-limitation is possible and does occur.[45]

The provisions for keeping numbers down, the actual means of self-limitation of populations, are forces, the working of which every naturalist has observed,

[40] S. Charles Kendeigh, *Ecological Monographs* 4, p. 309, July, 1934.

[41] L. S. V. Venables and David Lack, *British Birds*, 28: 7, p. 191, 198, December, 1934.

[42] T. H. Harrisson and John N. S. Buchan, *Jour. An. Ecol.*, 3: 2, p. 144, November, 1934.

[43] W. C. Allee, *Proc. Cambridge Phil. Soc.*, 9: 1, p. 42, January, 1934.

[44] Royal N. Chapman and W. Y. Whang, *Science*, 80: 2074, p. 298, September 28, 1934.

[45] F. G. Holdaway, *Ecological Monographs* 2: pp. 282, 283, July, 1932.

but which apparently no one has collated or emphasized. It would take a book to do justice to knowledge of the subject, although the ratio of what we know to what we do not know about it is small indeed.

In the case of yeasts, experimental results with which have been referred to, accumulation of ethyl alcohol produced by the plants themselves is the limiting factor.[46] Certain protozoans exhibit a similar phenomenon in microcosms, and Woodruff, who studied them extensively, shows[47] that both paramecia and hypotrichs excrete substances which are toxic to themselves and which tend to inhibit the rate of reproduction.

The roots of numerous plants are known to produce deleterious secretions, Schreiner and Reed reporting that these excreta are most toxic to plants of the same species,[48] a conclusion later confirmed by Pickering.[49]

A great variety of self-limiting factors on populations may be cited more briefly. Every observer can corroborate some of them from his own experience and no doubt also can add to the list. The eating of eggs is a self-inflicted check on populations and is exemplified in diverse groups. The flour beetle (under experimental conditions) was instanced in the preceding section, and the habit has been noted in nature in the case of the potato beetle. Fishes are known to eat their own eggs and the practice is known in even so advanced a group as birds.

Excess oviposition by membracids kills the twigs in which the eggs are laid; these terminals then dry and shrink, thus destroying the embryos. "The insect is its own worst enemy."[50]

[46] G. F. Gause, "The Struggle for Existence," p. 75, 1934.

[47] L. L. Woodruff, *Jour. Exp. Zool.*, 14: 4, 575–582, May, 1913.

[48] O. Schreiner and H. S. Reed, *Bul. Torrey Bot. Club*, 34: 6, 279–303, June, 1907.

[49] Spencer Pickering, *Ann. Bot.*, 31: 181–187, April, 1917.

[50] M. A. Yothers, *U. S. Dept. Agr. Tech. Bul.* 402, p. 26, February, 1934.

Devouring the young is known among insects (flour beetle, mole cricket), fishes (viviparous fishes, cod, trout, salmon), amphibians (salamanders), snakes and mammals. "Carnivorous males possess an instinct which prompts them to follow with expectancy the pregnant females before they have brought forth, and if they discover them, to devour the broods as soon as they are born."[51] In the London Zoological Gardens Superintendent Bartlett noted cannibalism as to young in the case of all carnivorous males except bears and in herbivorous males of prolific species.[52] Common observation proves it to occur not infrequently in certain domesticated mammals.

The shading out of their own seedlings by trees and other plants, another control exerted by adults against immature of their own kind, is a phenomenon annually occurring on a vast scale.

Infant cannibalism is known among mollusks, insects (dragonflies, flesh flies, flour beetles), spiders, fishes and salamanders.

Birds are known to indulge in a variety of practices which have the effect of limiting populations. In numerous species desertion of the eggs on slight provocation has been observed, and colonial birds such as pelicans have been known to abandon their eggs *en masse*. Certain birds, as cormorants, gulls, terns, herons and owls, begin incubation with deposition of the first egg; this results in the eggs hatching at intervals, in unequal growth of the young, and, in consequence, considerable mortality. Taverner notes with respect to double-crested cormorant that "in the latest stages observed we did not see a nest that contained more than one bird."[53]

[51] George Paulin, "No Struggle for Existence. No Natural Selection. A Critical Examination of the Fundamental Principles of the Darwinian Theory," p. 51, 1908.

[52] *Ibid.*, p. 38.

[53] P. A. Taverner, *Canada Geol. Surv. Mus. Bul.* 13, p. 7, 1915.

Some birds normally have a conspicuous proportion of non-breeding individuals (e.g., scoters, shorebirds) while others breed at irregular intervals, as vultures. "Periodic extensive non-breeding is not uncommon in the arctic among certain birds."[54] These include loons, jaegers, gulls, ducks, geese, owls and others. Similar restrictive habits exist among mammals, that of individual non-breeding being well known in herding kinds, as sea-lions, and ruminants, and that of breeding at intervals of more than one year in bears and elephants.

Biennial fruit and seed production is a very common plant phenomenon (apples, oaks, mullen) and fruition at longer and irregular intervals also is well exemplified (pines, agaves, beech).

An evident safety-valve for populations that must be classed among the self-limiting factors is the habit of irruptive migration. Most of the individuals participating in these outbursts never return to the place of origin; in fact, in characteristic instances they make no effort to do so. Without doubt most of the individuals perish in a relatively short time and the breeding population is thus very effectively reduced. Some of the creatures exhibiting irruptive migrations are hawks, owls, sand grouse, sharp-tailed grouse, ptarmigan, the red-breasted nuthatch, squirrels, mice, lemmings, termites, ants, moths and butterflies.

Self-limitation of populations is so well recognized in the human race that we have familiar terms referring to its various phases, as contraception, abortion, infanticide, celibacy, polyandry and polygamy, not to mention a host of other practices not so widely accepted. It is apparent that self-limitation of populations is a wide-spread, it may be a universal, phenomenon. In most cases it can not be regarded as competition; in fact, it exemplifies what we find on due reflection to be the almost omnipresent evasion of competition.

W. R. Thompson says: "The simple truth is that the natural control of organisms is primarily due, not to any complex cosmic mechanisms or regulatory factors, but rather to the intrinsic limitations of the organisms themselves."[55] If this conclusion be accepted it means the death knell of the whole series of natural selection subtheories as to "protective adaptations," dependent, as they are, on a postulated high degree of "natural control" by selective predation.

The Malthusian Doctrine and Natural Selection

Malthus "later gained wider fame by being the acknowledged source of Darwin's long sought concrete cause of evolution, Natural Selection."[56]

> A chance reading of the *Essay* in which the phrase "struggle for existence" struck an answering chord, stimulated Charles Darwin to find the key to biological change in the process of natural selection brought about by this struggle for existence."[57]
>
> It is well known that he [Darwin] accepted the Malthusian view of over-population and deduced from it the struggle for existence. . . . He took his logical method from Malthus. He began from a single definite fact, based on observation, namely, that the number of individuals increases at a rapid rate. He considered what would be the result of this tendency should it act unchecked; he concluded that it would lead to a struggle for existence, and he called the deduction thus arrived at a natural law.[58]

Malthus was canny in expressing himself on the mode of increase; he says, for instance, in regard to the human race, that "population, *when unchecked*, goes on doubling itself," and in his more general statement, "the germs of existence contained in this earth, *if they could*

[54] G. C. L. Bertram, David Lack and B. B. Roberts, *The Ibis*, 13 ser., IV 4: p. 827, October, 1934.

[55] W. R. Thompson, *Parasitology*, 21: 3, p. 273, September, 1929.

[56] E. M. East, "Mankind at the Crossroads," p. 47, 1923.

[57] Reference No. 1, p. 745.

[58] E. Radl, "The History of Biological Theories," Transl. by E. J. Hatfield, pp. 17, 18, 1930.

freely develop themselves, would fill millions of worlds." As prophecies, such remarks are perfectly safe. They are not put to the test because populations always have checks; are rarely if ever able to develop freely.

The potentiality for rapid (if you will, geometric) increase of organisms is undeniable, but realization of that potentiality does not necessarily follow. It may be achieved at times by man and by domesticated and other organisms, profiting by man-made alterations of environments, but these occurrences can not be considered representative of what may happen under natural conditions. In nature, geometric increase only occurs subsequent to the low point in cyclic or other severely fluctuating populations, and in those is promptly checked as the average maximum abundance of the species is again approached.

As has been pointed out,[59] selectionists have been rather naive in their disquisitions on populations, which although essentially stationary yet are said to be increasing at a geometric rate. Wallace, for instance, says: "As all wild animals increase in a geometrical ratio while their actual numbers remain on the average stationary, it follows that as many die annually as are born."[60] And in another connection: "We must never for an instant lose sight of the fact of the enormously rapid increase of all organisms. . . . Then, never forgetting that the animal and plant population of any country is, on the whole, stationary, we must be always trying to realize the ever-recurring destruction of the enormous annual increase."[61]

[59] Charles Clement Coe, "Nature versus Natural Selection: An Essay on Organic Evolution," pp. 43–59, 1898.

[60] A. R. Wallace, "Contributions to the Theory of Natural Selection. A Series of Essays," p. 309, 1870.

[61] A. R. Wallace, "Darwinism: An Exposition of the Theory of Natural Selection with Some of Its Applications." Ed. 2 (Reprint with corrections of edition 1 (1889), p. 122, 1890.

Now it is manifest that both of these propositions as to populations can not be true. If the population is stationary, it can not be increasing at a geometric rate, or if it has the latter attribute it can not be stationary. Although populations fluctuate, often abruptly, the average, so far as we can tell, remains about the same over long periods. From a subsistence standpoint this can only mean that the average consumption of food is about the same from year to year.

Further implication of this state of affairs is that food as a rule being in excess (as shown in a preceding section), and the quantity required remaining about the same from year to year, there can not be as a rule any broadly significant competition for food or sustentative selection in a state of nature.[62]

Since food as a rule is in excess and populations in the long run hold to average numbers, it is evident that they are checked short of a subsistence limitation. "If they could multiply unchecked, that is, without the loss of many of their progeny, every species would fill up its area of occurrence and exhaust the whole of its food supply, and thus bring about its own extermination. This seems to be prevented in some way, for as a matter of fact it does not happen."[63] The phenomenon is another of the apparently automatic devices of nature for preserving numerical relationships, the real essence of which seems to elude comprehension.

If sustenance is not the limiting factor, as seems clearly to be the case in general, inquiry immediately arises as to what is. The writer is not one of those who believes that everything can be explained; the matter can, however, be discussed. Besides subsistence effects we have in previous pages dealt also with space effects. The question relative to them that is pertinent to the present section

[62] Roswell H. Johnson, *Am. Nat.*, 46: 546, 372–376, June, 1912.

[63] Reference No. 15, p. 44.

is whether, in their working out, a struggle for existence and survival of the fittest are apparent.

For a beginning it may be pointed out that the space effect or limitation of population, as density increases, characteristically operates through a lowered rate of reproduction. This phenomenon is far from according with the postulated geometric increase and intensified mortality called for by the Malthusian principle of population and the Darwinian theory of natural selection.

Even if birth rates do decrease, however, a reproductive excess always remains and we may inquire whether the normal process of its disposal seems to bring into play a struggle for existence and a survival of the fittest. In the case of short-lived organisms, where the parent generation has passed before the filial generation matures or is even born, elimination proceeds until, on the average, there are just enough of the new generation left to replace the old. In the case of longer-lived forms where the parent generation may live concurrently with the new, elimination is even more severe, leaving only enough young ultimately to replace the number of the old that perish in the average span of a generation. In either case mortality is conspicuously greater among the young, and as a rule the rate of elimination is directly proportional to the degree of immaturity.

The losses in the egg stage of animals and in the seed or spore stage of plants are well known to be excessive. Many birds, for instance, suffer from 50 to 75 per cent. destruction of eggs. That fitness, at least of the eggs, is not the cause is shown by experience with game species that are artificially propagated. In the case of the bob-white, for example, with about 64 per cent. of nest (and presumably therefore of egg) destruction in the wild, from 75 to 85 per cent. of the eggs can be hatched under bantams or in incubators.

Tremendous losses in the egg stage of various animals are so familiar a phenomenon that few instances need be cited. The mass destruction that often overtakes the eggs of frogs, toads, salamanders and of various insects that oviposit in temporary pools is known to all observers. Here again total annihilation by the drying up of the pools is in no way affected by "fitness" of individuals. It is conceivable that partial elimination might be so affected, but where destruction occurs it is usually complete.

When miles long ridges of pelagic ova are destroyed by being washed up on shore, when the eggs of a multitude of parasitic forms perish by the thousands because they have not had the luck to find a host, when annual crops of seedlings are all suppressed in forests for decades, perhaps, until there is a chance opening in the canopy from which as seeds they fell, it is idle to speak of the "survival of the fittest." It would be easy to catalog case after case of excessive egg, seed or spore production cut down promptly in those or in immediately succeeding stages, but it is unnecessary as the phenomena of which examples are here given are recognized as being the rule in nature. In fact, the normal process seems to include tremendous elimination of the young with an intensity proportional to their immaturity; this in itself goes far to insure little increase in demand either for food or space (*i.e.*, the period when the population is really above normal is very brief compared to the length of a generation); there is subsequent survival of a very high proportion of those escaping the early sweeping destruction, these survivors mostly living to propagate their kind. In other words, there seems to be a relatively small proportion of the total elimination (hence selection) among those that mature and provide for continuity of the race.

From prevailing accounts of natural

selection we are led to think that it is the result of competition between evenly matched individuals, in which "a grain in the balance may determine which individuals shall live and which shall die."[64] Since, as we have just noted, however, a high proportion of mortality occurs in the immature stages and few therefore attain the adult state, there is little or no chance for competition of the oncoming with the outgoing generation even in cases where they are alive at the same time. To refer to the usual sweeping elimination of inert eggs and helpless babes as a struggle for existence is a travesty. These immature forms have no power to resist; they merely await their fate, and whether that fate is life or death in a great majority of cases does not depend on individual qualifications. The weight of evidence indicates that the elimination of the immature is highly indiscriminate and that the survivors are the lucky rather than the "fit."

Conclusions

Superficially considered, the Malthusian principles seem very impressive, but they do not bear analysis. It is manifest throughout nature, and even in the highly artificial case of humankind, that populations are not necessarily limited by the means of subsistence, and that they do not always increase where the means of subsistence increase. Malthus mentioned but did not dwell upon limitations of space. These are important, and in a broad sense controlling, but they also do not ordinarily depend upon subsistence.

Malthus's postulated geometric increase of population is not the rule in nature; it is merely a potentiality, rarely realized. Populations usually are checked far short of a subsistence limitation. Automatic restriction by lowering of birth rate in response to density and by a great variety of self-limiting phenomena, together with sweeping indiscriminate destruction of immature forms, involving little or no actual competition either among themselves or with adults, seem to be the principal factors involved in maintaining the stability of populations. These facts leave so little basis for the Darwinian theory of natural selection, largely inspired by the mistaken postulates of Malthus, that it is difficult to understand its popularity.

The more we learn about organic populations, the more it seems that there are automatic tendencies toward the preservation of numerical relationships. This automatic regulation is not rigid, the balance of nature is fluctuating, but it is always striving for equilibrium. Man may not want to admit the principle of automatic population control, as so doing interferes with his playing with the idea that ultimately he can explain it all—an idea to which the writer does not subscribe.

[64] Charles Darwin, "The Origin of Species by Means of Natural Selection or the Preservation of Favored Races in the Struggle for Life," Reprint 6th Ed., pp. 454–455, 1912 (?).

SCIENCE SERVICE RADIO TALKS

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CARE OF THE HEALTH IN HOT WEATHER

By Dr. ROBERT OLESEN

MEDICAL DIRECTOR, UNITED STATES PUBLIC HEALTH SERVICE

WHILE the underlying principles of personal hygiene observe the same general trends at all times, the actual measures to be instituted vary somewhat in kind and degree with the seasons. This is particularly true during hot weather, when certain alterations of conduct are desirable if unnecessary discomfort or actual illness is to be avoided. However, there is no new or startling advice, instruction, rule or magic formula for safeguarding the health at such times. Health maintenance is primarily an individual responsibility, the essential factors usually being simple, accessible and practical. Hot weather hygiene may be expressed in a single word—moderation.

In summer one's thoughts naturally and very properly turn to the prospect of a vacation, with a change of scene and respite from customary occupations. The wise employer, realizing that mutual benefits will accrue, insists that full and continuous vacations be taken by his employees. Quite obviously every person, whether employed or not, would be benefited by a change of environment. However, for financial or other reasons, many persons are unable to spend the entire warm season or even a small part of it, in a sojourn away from home.

There are numerous compensations for the person who must remain at home during summer. First and foremost is the fact that the local health department is or should be continuously providing health safeguards. In cities the milk, water and food supplies are usually carefully supervised. Moreover, modern sewerage facilities are available and insect pests are infrequent. The freedom of one's own home and proximity to personal possessions are likewise conducive to comfort and enjoyment. There are times when a vacation at home affords the best possible opportunity for rest and recuperation. However, many of these home advantages are offset by the intensity of the summer heat and the sameness of the surroundings.

When an "away from home" vacation is decided upon adequate health protection should be a prime consideration. The selection of a suitable vacation place is an important matter requiring the exercise of good judgment and careful attention to numerous vital health factors. Thus, safe milk and water, wholesome food, restful surroundings and opportunities for zestful recreation should be insisted upon. The onset of the hot season is a signal for greatly reduced mental and physical activity—a time for recharging the human "battery."

The vacation should be a time for rest and recuperation as well as for pleasurable refreshment of the strength and spirits. To make this period so strenuous that one returns to his customary duties completely fatigued can scarcely be termed sensible or profitable. Furthermore, full advantage should be taken of the opportunity for exercise in the open. To remain indoors constantly, to spend an excessive amount of time at the card table or to keep unnecessarily late hours is to defeat the object of the vacation.

But whether the heated term is spent

in customary surroundings or away from home there are certain hygienic principles that can, with profit, be observed. On very hot days it is a wise general rule materially to reduce the mental and physical speed at which the individual customarily operates. This injunction is particularly applicable to workers of all kinds, both in offices and in the open. Considering the relatively small amount of work performed under adverse conditions it is often justifiable to curtail the working hours during excessively hot weather. Such expedients as short rest periods, cooling drinks, protection from direct rays of the sun and cooled work places are reflected in the increased comfort, contentment and increased efficiency of the favored workers.

It is fortunate that hot weather fosters a disinclination for heavy and hot meals because light, nutritious and easily digestible food is obviously more suited to the season. Generally speaking, fried foods, pastries, excessive amounts of sweets and other articles contributing materially to heat production should be curtailed. On the other hand, fresh ripe fruits, fresh garden vegetables, salads, cereals, milk of good sanitary quality and milk products satisfy the hunger while contributing but little to heat production. Even so the diet should be properly balanced by partaking in moderation of standard articles of food. When meals are eaten unhurriedly in cool, pleasant and inviting surroundings the appetite is stimulated and the digestion is aided. Furthermore, the jaded summer appetite may be spurred when artistry and imagination are used in preparing and serving food.

An abundance of water, internally and externally, is a necessity during hot weather. One or more tepid tub baths or cool showers daily cause discomfort and fatigue to be replaced by a feeling of well-being. A swim in a pool or a body of water of good sanitary quality is cleansing, cooling and provides needed exercise that might not otherwise be obtained.

Just how much water should be consumed in hot weather depends largely upon the work performed, the atmospheric temperature and the relative humidity. In any event pleasantly cool water should be consumed in fairly liberal quantities but not too hastily. The excessive use of iced or sweetened drinks is apt to exert a detrimental influence upon the digestion.

It seems almost superfluous to reiterate that summer clothing should, for the comfort of the wearer, preferably be light in weight and color and porous in texture. Such clothing permits evaporation of perspiration and allows air to reach the skin readily. Frequent changes of clothing, particularly of that next to the skin, is especially conducive to comfort. It is earnestly to be hoped that before long men may share some of the comforts now monopolized by women. Thus, the discarding of coats, vests, collars and ties would add greatly to masculine comfort while not too severely outraging the dictates of fashion and good taste.

The keeping of late or irregular hours during the summer is particularly undesirable and even harmful, for health maintenance requires an adequate amount of sleep. Because of intense heat, especially at night, it is sometimes difficult to secure the requisite amount of refreshing and untroubled sleep. At such times an electric fan may be of value. However, the air currents produced by the fan should not be permitted to play directly upon the body, lest chilling and illness occur. The siesta or midday nap, a fixed habit in tropical countries, is a valuable aid in insuring adequate rest during hot weather. Whether one actually sleeps, reads or

lies quietly for a short time in a darkened room, this brief respite from routine affairs is an excellent "shock absorber." In any event it is wise to allot regular and sufficient time for sleeping purposes.

Summer is not a time for excessive activity. Quite on the contrary exercise suited to the occasion, as well as the requirements of the individual, should be sought. Constant automobile riding is strongly to be deprecated, especially when interspersed with irregular hours, injudicious eating and insufficient exercise. Moderate indulgence in walking, swimming, dancing, golf, tennis, horseback riding, archery, quoits and similar diversions will provide pleasant and needed exercise during hot weather. However, participation in these sports may well be confined to the early morning and later afternoon, when the heat of the sun is less intense.

Swimming, one of the most popular of summer sports, has been greatly abused by the careless and unthinking. It is obvious that so useful a diversion should be surrounded with adequate safeguards. Ability to swim and knowledge of rescue methods are prime requisites for entering the water. Needless to say, water used for bathing should be free from pollution lest disease be widely disseminated. By refraining from bathing immediately after eating, remaining in the water only for short periods and avoiding chilling of the body, this excellent sport may be enjoyed without fear of unfavorable reaction.

A coat of tan should be acquired gradually, otherwise one may suffer unnecessarily and even intensely from sunburn. The bronzed skin of the lifeguard may well be envied, but it should be remembered that a healthy tan is the result of weeks of gradual exposure to the sun rather than an intensive burn acquired during a day's sojourn at a bathing beach.

As the mind, as well as the body, is in need of periodical rest and diversion, an admirable opportunity is afforded during the summer for mental hygiene. The reading of light, diverting and not too stimulating literature is often soothing and conducive to a feeling of well-being. By substituting new, interesting and less exacting mental activities for those customarily pursued interest and enjoyment can be induced. Satisfactory mental rest can often be secured easily and naturally by working with the hands instead of the head. Indulgence in a hobby is an excellent way of mitigating the discomforts of heat. Thus, the identification of birds, trees, flowers, plants and insects may be cited as useful and diverting interests. There are many hobbies that are not strenuous in their demands, yet provide mild, soothing and helpful mental exercise. Such relaxation is particularly relished by a person who is ordinarily engulfed by concentrated mental requirements.

Comfort during hot weather is due in no small part to a complacent mental attitude. A philosophical state of mind, freedom from worry and inclination to benefit as much as possible by the respite from ordinary duties are all conducive to health and happiness. When an unruffled state of mind is coupled with reasonable observance of hygienic principles a winning combination results. Moreover, when the summer season has been properly spent the arduous duties of fall and winter may be resumed, with confident assurance that the mind and body are better prepared to meet the more exacting demands that will almost certainly be forthcoming.

THAT PERENNIAL PUBLIC ENEMY, POISON IVY

By Dr. JAMES F. COUCH
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VACATION days will soon be here again, and the great outdoors, with its green meadows and purling brooks, its wooded dells and surfy shores, beckon irresistibly to the nature lover. Gladly humanity responds to the invitation and pours out of the sweltering cities into the cool calmness of the countryside. Most of these people will return refreshed and recreated by the holiday; some, however, will encounter that perennial public enemy, poison ivy or poison oak, with the result that their vacation will be turned into a period of acute suffering from the effects of that pest. A few will escape with nothing worse than some intensely itching blisters, but some will suffer a general reaction to the poison, accompanied by swelling of the affected parts, chiefly the face and hands, and the extremely susceptible will be made so acutely sick as to be confined to bed for several days. Ivy poisoning is always discomforting and may become very serious. Four cases of death have been reported, which indicates that it is not to be considered merely a trivial affection.

Ivy poisoning always results from direct or indirect contact with the plant and the easiest way to avoid it is to learn how to recognize the plant and then to keep away from it and from anything else that may have been in contact with it. Dogs and cats may run through patches of poison ivy and brush off the poison on their fur. Susceptible persons who may then pet these animals are very likely to contract a case of ivy poisoning without having been anywhere near the plant.

Poison ivy is classified by botanists in the genus *Rhus*. About twenty species of this genus are known to cause the characteristic dermatitis. Many other species of *Rhus,* like most of the common sumacs, do not cause this dermatitis. Of the poisonous species, three are of especial note. Two are of shrubby growth but may be found climbing upon walls and trees, like the true ivy. In the East the principal dangerous species is *Rhus radicans* L. and is popularly called poison ivy. It is also called poison creeper, markweed, mercury, picry and three-leaved ivy. Some confusion is caused by the fact that the name poison ivy is applied in some sections of the South to mountain laurel, a plant that does not cause inflammation of the skin or dermatitis.

In the Mountain and Pacific Coast states grows another shrubby species, *Rhus diversiloba* Torr. and Gray, which is commonly known as poison oak, a name that is often used also to designate the Eastern poison ivy. The third poisonous species is *Rhus vernix* L., known as poison sumac, and also called swamp sumac, poison ash, poison elder, poison dogwood and thunderwood. This species grows in bogs only and so is less accessible and causes less trouble than the other two. Poison sumac grows as a tall shrub or sometimes as a tree 20 to 30 feet tall. Poison ivy is really misnamed. The true ivies are not poisonous to the touch, but Captain John Smith, of Jamestown fame, after a painful experience with the plant, fancied that *Rhus radicans* resembled English ivy and gave it the name by which it has gone ever since.

Poison ivy and poison oak can easily be recognized by the characteristic form of the leaf, which is divided into three leaflets and accounts for the wholesome maxim "Leaflets three, let it be!" After

the leaves have fallen in the autumn, the plant is still dangerous and may then be detected by the white berries that remain well into the winter. Virginia creeper is often mistaken for poison ivy, but here the leaf is divided into five leaflets instead of three. Virginia creeper does not cause dermatitis.

In swamp sumac the leaf is divided into 7 to 13 leaflets instead of three, and these are 3 to 4 inches long with a scarlet-colored midvein. The arrangement of the leaflets is like that found in other sumacs. I would suggest that you get some illustrations of these plants and familiarize yourselves with their appearance so that you may readily recognize them. A number of excellent pictures of the poisonous *Rhus* are published in Farmers' Bulletin No. 1166, issued by the United States Department of Agriculture, and serve well to identify these plants.

Poison ivy, poison oak and poison sumac all contain a milky juice that is very irritant and can blister the skin on contact. I doubt if any one is immune to this poison, although some people are much more resistant than others. Some are so susceptible that the slightest contact seems sufficient to cause a severe reaction. There does not seem to be any foundation for the stories that certain races, like the Indians, are immune to ivy poisoning. Even those who are quite resistant will be blistered if the juice of these plants comes in contact with tender skin and is not washed off before it penetrates. Persons who are relatively non-susceptible should, nevertheless, treat poison ivy with respect because repeated contact with the plant is known to sensitize the body to the poison so that a resistant person may become very susceptible in time.

A number of cases of *Rhus* dermatitis has been reported in which the irritation was contracted by handling articles decorated with Japanese lacquer. This lacquer is made from the juice of a species of *Rhus* that grows in China and Japan. The sufferers developed typical cases of ivy poisoning after contact with these articles. However, these articles will affect only the most sensitive persons and are quite safe for most people to handle.

Occasionally there is a report that some animal has been poisoned by poison ivy, but this is rare. Probably the fur of most animals prevents the irritating substance from reaching the skin and so protects them. Cattle and sheep graze upon poison ivy with apparent impunity and it seems to be true that the poison does not affect the mucous lining of the gastro-intestinal tract.

It is said that a person sensitive to ivy poisoning may render himself immune for a season by eating three of the leaves in the spring. This report comes from a variety of sources and may have some foundation. However, a few cases are on record in which persons who ate poison ivy leaves were made sick, and Dr. J. B. McNair, in his exhaustive book, "Rhus Dermatitis" (University of Chicago Press, 1923), records the deaths of two children from eating the berries. There is a story that the Indians of the Pacific Coast used this method and never suffered from ivy poisoning, although they roamed the mountains during the summer without much clothing on, and poison oak grows very luxuriantly in those localities. A method for immunizing people based on this idea has been developed by a member of the medical profession, and good results have been claimed for it.

The isolation of the peculiar irritant poison of these plants early challenged the skill of our chemists and it was soon found that this is no common sort of poison but something that is very elusive and, once separated from the plant, readily changes into other forms so that the task of isolating it in a pure condition is extremely difficult and requires the utmost patience and dexterity. We have the results of a large number of investi-

gations of this poison that give us much information concerning it. Poison ivy was studied by Pfaff[1] and by Acree and Syme.[2] A thorough study of poison oak was made by McNair,[3] and poison sumac was investigated by Stevens and Warren[4] and by Warren.[5]

All these chemists obtained from the plants oily substances that were very toxic and would produce blistering in incredibly small quantities. The poison was named "*toxicodendrol*" by Pfaff and appears to be present in all species of *Rhus* that cause dermatitis. It is present in the roots, stems, leaves and berries, although the ripe berries are said to be practically non-poisonous. Toxicodendrol, literally "the phenol from the poison tree," is a complex substance that belongs to the group of substances called phenols by the chemist. There are other members of this group that can blister the skin, but none is known that is so active as this one from poison ivy. Toxicodendrol is readily soluble in fats and so easily penetrates to the lower layers of the human skin, where it sets up the painful irritation so well known to its victims. This action has even been patented in the United States by some enterprising gentleman, who developed a blistering lotion of which the active ingredient is toxicodendrol.

Evidently the best method to use in dealing with this irritant pest is to avoid it and escape its effects. Poison ivy, however, is so ubiquitous and grows so often in dark and shaded places where it is not easily recognized that it is not always possible to evade it. When it is growing along paths, by the roadside, in the garden or near the house where it is difficult to avoid it, the plant should be eradicated. This can be accomplished by digging it out by the roots, which is the most effective method of disposing of it permanently. However, if you do not care to get so close to the pest as digging requires, other methods are available. These are fully described in Farmers' Bulletin No. 1166, already referred to, a copy of which should be available to every one interested.

Let us suppose that you have come into contact with poison ivy. What are you going to do about it? The best method is to wash the exposed areas of the skin immediately with soap and hot water. Yellow laundry soap is recommended as best, since this contains an excess of alkali which dissolves the poison. It is advisable for sensitive persons to take this precaution after every trip through the fields where poison ivy may grow, whether actual contact has taken place or not. Sometimes sensitive persons on a scientific excursion or in pursuit of their business affairs may find it necessary to pass through areas where poison ivy is growing, and it is desirable that these persons have some type of protection. Dr. McNair suggests that the hands and arms be bathed in 5 per cent. solution of ferric chloride in equal parts of glycerin and water before the sensitive person ventures into the infested places. Another preventive suggested is to bathe the exposed parts of the skin with a 5 per cent. solution of copperas or ferrous sulfate before visiting those areas. One should always remember that in the majority of cases it is the hands that come in contact with the poisonous plant. The hands get covered with the poison, which is then carried to any other portion of the body that the hands may happen to touch. If one suspects that he has touched poison ivy, he should be careful not to spread the poison by rubbing his face or arms or touching any other part until he has thoroughly washed the poison off his hands.

After contact the rash or blistering may begin to appear within a few hours to two or three days. Reddish blotches or wheals that itch distractingly or multi-

[1] *Jour. Exp. Med.*, 2, 184, 1897.
[2] *Am. Chem. Jour.*, 36, 391, 1906.
[3] *Jour. Am. Chem. Soc.*, 43, 159–64, 1921.
[4] *Am. Jour. Pharm.*, 79, 499–522, 1907.
[5] *Pharm. Jour.*, 83, 531–2, 562–4, 1909.

tudes of small itching blisters make their appearance and tempt one to ease the torment by scratching the skin. Scratching is to be avoided because it spreads the poison and at the same time breaks the outer layer of cuticle and allows the poison ready access to the lower layers of the skin. A large number of remedies has been suggested, and in particular cases many of these are successful. In my own experience I have found an oxidizing agent is the most rational and satisfactory treatment. Toxicodendrol is very susceptible to oxidation and if brought into contact with some substance capable of liberating oxygen it will be converted into an inert resin that can not cause blistering. One of the cheapest, most common and harmless oxidizing agents is potassium permanganate, which may be obtained at any drug store. In a strength of five per cent. in water potassium permanganate stops the itching almost immediately by destroying the poison and so gives quick relief. It may be applied as a wash using a piece of absorbent cotton or cloth and dabbing it on the affected spots until the itching stops. Blisters should be opened with a sterile needle to allow the remedy to come in contact with whatever poison may be contained inside them.

This remedy was suggested seventy years ago by John M. Maisch, of Philadelphia,[6] and is still the standard treatment. It has one disadvantage. As it gives up its oxygen, potassium permanganate turns brown and leaves a brown stain on the skin. This should be washed immediately after each application. The stain may be removed slowly by washing with soap and water or more quickly by a one per cent. solution of oxalic acid or by sodium bisulfite, sodium hyposulfite of the photographers or by hydrogen peroxide, although the warmth occasioned by the last mentioned may be disagreeable to some people. The oxalic acid will cause a stinging of raw surfaces which, however, is mild and not objectionable to most persons.

Generally one thorough application of potassium permanganate is sufficient but stubborn cases may require several applications. The permanganate is harmless to the most delicate skins, particularly if the skin be washed thoroughly after each application. After itching has stopped the affected area should be allowed to heal under antiseptic conditions. A soothing ointment such as zinc oxide or boric acid ointments should be spread gently over the skin to assist nature in repairing the injured tissues. But an ounce of precaution is always worth a pound of cure. Learn to recognize the plant and keep away from it.

[6] *Proc. Am. Pharm. Assoc.*, 13, 166–74, 1865.

DR. JOHN GORRIE—INVENTOR OF ARTIFICIAL ICE AND MECHANICAL REFRIGERATION

By Professor GEORGE B. ROTH

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THE proclamation by the governor of Florida[1] of the week of August 11 to 17 as "Ice Memorial Week" had associated with it the name of an early distinguished and eminent Southern practitioner of medicine, Dr. John Gorrie, of Apalachicola, Florida.

Relatively few medical men outside of the state of Florida have ever seen his name, although the state of Florida about twenty years ago placed a statue of Dr. Gorrie in Statuary Hall of the Capitol of the United States.[2]

The accomplishments of Dr. Gorrie were not wholly in the realm of medicine, the memorial in Statuary Hall representing his ability as an inventor rather than as a practitioner of medicine, having been placed there largely through the efforts of those interested in ice manufacture and mechanical refrigeration to commemorate his invention of the ice-machine.

The patent, No. 8080, which was granted Dr. Gorrie on May 6, 1851, is considered to be the first U. S. patent on an apparatus for the mechanical production of ice, the previous patents being non-workable.[3]

Dr. Gorrie's apparatus was based on the well-known law that the release of a compressed gas (in this case, air) results in the absorption of heat.

Dr. John Gorrie was born in Charleston, S. C., on October 3, 1803. His early education was obtained in the schools of that city; his medical education from a Northern institution. His biographers[4] state that he received the degree of doctor of medicine in 1833 from the College of Physicians and Surgeons of New York City, a statement which can not be verified, as the name of John Gorrie is not to be found in the list of graduates for 1833 from that institution, nor in fact in its "Index to Alumni up to 1880."

Within a year after graduation he went to Apalachicola, Florida, which was then an important seaport, being the outlet for all the cotton grown in the Chattahoochee Valley in Georgia and Alabama. Here he resided until his death in 1855. He at once became a central figure in the life of Apalachicola, becoming postmaster in 1834 and retaining the position until 1838. He was a member of the city council and city treasurer from 1835 to 1836, mayor in 1837. In 1839 he withdrew from public office to devote his whole attention to medicine and investigation.

The greatest drawback to the growth of Apalachicola was the prevalence of fever in summer, and to this he gave his thought. He found it impossible to successfully treat his fever cases during the hot months. Believing that the excessive heat was the largest obstacle which he had to combat in his fight against fever, he devoted all his energies to air-cooling the rooms in the hospitals for his fever patients. This led to the development of the ice-machine, ice being necessary to air cooling and air conditioning. Under the nom de plume of "Jenner" he is said to have written a series of eleven articles in 1844 for the *Commercial Advertiser* of

[1] *Jour.* Am. Med. Assn., 105: 441, 1935.

[2] "U. S. Statutes at Large," Vol. 38, Pt. 2, p. 1615; also *Ice and Refrigeration*, 46: 311, 1914.

[3] *Ice and Refrigeration*, 21: 45, August, 1901.

[4] "Dictionary of American Biography," Vol. 8, p. 436; also *Ice and Refrigeration*, 46: 311, June, 1914.

Apalachicola, on the prevention of malarial diseases. A paper in the *New Orleans Medical and Surgical Journal*[5] on "The Nature of Malaria and Prevention of its Morbid Agency," is of interest in connection with the modern movement towards air conditioning sick rooms and hospitals, since he gives in detail the method which he employed and which undoubtedly led to the invention of the ice-machine as a by-product.

In this paper he wrote about malaria as follows (page 767):

Although we know nothing certain of the elementary character of malaria, yet it is generally believed, and has been abundantly proved, that the circumstances essential to its existence are organic decomposition, moisture and heat.

For its prevention he used the following means (page 758):

[5] *New Orleans Medical and Surgical Journal*, 1854–1855, pp. 616–634, 750–769.

The mechanical contrivance by which I propose to take advantage of these properties of ice, so as to effect a refrigerating and depurating ventilation, is . . . simple. My whole process consists in first suspending an ornamental mantel vase, urn or basin, in which the ice is placed, by chains like a lamp or chandelier, from the center of, and close to the ceiling of a room. Next, over this vessel an opening is made in the ceiling from which a pipe is extended, between the ceiling and the floor above, to the chimney of the house . . . through it (chimney) and the pipe, instead of the doors and windows, all the air as far as possible . . . ought to be received. In such an arrangement the external and fresh air is attracted . . . to the upper part of the room, in consequence of the partial vacuum formed around the ice, and thence, after being cooled, it is dismissed in a diffused shower . . . to the floor to be discharged by the lower pipe.

His explanation of the beneficial effect of this procedure is as follows:

The solution of ice . . . is attended with a number of chemical actions on air . . . and are all concurrent on one grand effect—the decom-

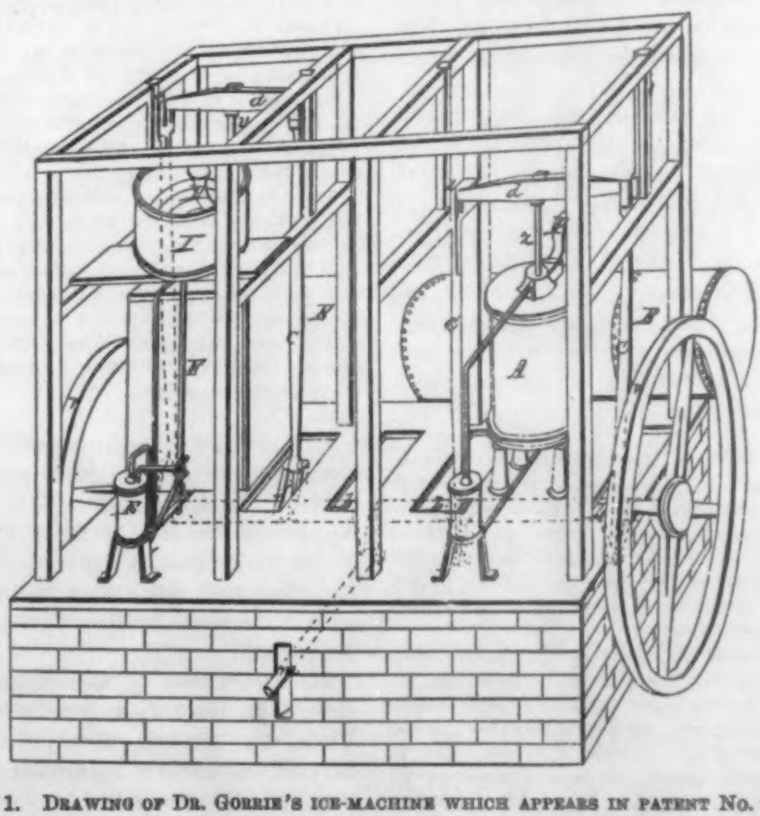


FIG. 1. DRAWING OF DR. GORRIE'S ICE-MACHINE WHICH APPEARS IN PATENT No. 8080.

position of Malaria; mixed with warmer air, it reduces its temperature and in the same process causes it to deposit its continued vapor in the form of water; and, at the same time, it absorbs other volatile matters and extraneous gases contained in the air. Receiving, as part of the device, the air intended to be acted upon through a long conduit like a chimney, lined with carbon dust in the form of soot, must also tend, from the affinity of carbon for vapors and organic oils, to decompose Malaria.

He further mentions in this paper having invented a machine for manufacturing ice, as well as explaining its principle and construction.

The patent on the ice-machine was issued to John Gorrie of New Orleans, the reason for this being that he was obliged to go to New Orleans to secure funds necessary to perfect his machine and make application for the patent.

The model of the ice-machine which Dr. Gorrie submitted to the Commissioner of Patents to secure his patent now resides in the U. S. National Museum. It is lacking in some of its minor parts.

Fig. 1 is a drawing of the machine which accompanied the application and which appears in the original patent, together with seven other views of it.

Fig. 2 is a photograph of the model as it now exists in the U. S. National Museum. Both Figs. 1 and 2 show the machine as viewed from the front.

The essentials of the machine are clearly brought out in the patent, which stated them as follows:

It is a well-known law of nature that the condensation of air by compression is accompanied by the development of heat, while the absorption of heat from surrounding bodies, or the manifestation of the sensible effect, commonly called "cold," uniformly attends the expansion of air, and this is particularly marked when it is liberated from compression.

The nature of my invention consists in taking advantage of this law to convert water into ice artificially by absorbing its heat of liquefaction with expanding air. To obtain this effect in the most advantageous manner it is necessary to compress atmospheric air into a reservoir by means of a force-pump to one eighth, one tenth or other convenient and suitable proportion of its ordinary volume. The power thus consumed in condensing the air is, to a considerable extent, recovered at the same time that the desired frigorific effect is produced by allowing the air to act with its expansive force upon the piston of an engine, which, by a connection with a beam or other contrivance common to both, helps to work the condensing-pump. This engine is constructed and arranged in the manner of a high-pressure steam-engine having cut-offs and working the steam expansively. When the air, cooled by its expansion, escapes from the engine, it is made to pass round a vessel containing the water to be converted into ice, or through a pipe for effecting refrigeration otherwise, the air while expanding in the engine being supplied with an uncongealable liquid whose heat it will absorb, and which can in turn be used to absorb heat from water to be congealed. By this arrangement I accomplish my object with the least possible expenditure of mechanical force, and produce artificial refrigeration in greater quantity from atmospheric air than can be done by any known means.

The apparatus for producing the refrigeratory effects before stated consists, essentially, of a large double-acting force-pump, A, with its jet-pump D, Figs. 1 and 4, condensing-tub R, and worm P, as represented in the drawing No. 4, a reservoir, B, made of such metal in the manner of a steam-boiler, a double-acting expanding-engine, C, provided with cut-offs, a jet-pump, E, a tub, I, and worm H, for cooling water, the engine C and the chamber G above it being inclosed in an insulating-box, F, which box, together with the worm and tub H, are inclosed in a second insulating room or chamber, K. The pumps, engine, and other moving parts are provided with the necessary mechanical appliances for putting and keeping them in motion and connecting them with the prime mover, which may be either a steam-engine or other available power.

In 1854 Dr. Gorrie issued a 15-page pamphlet (printed by Maigue and Wood of New York) entitled "Dr. Gorrie's Apparatus for the Artificial Production of Ice in Tropical Countries." In it he describes and illustrates the apparatus with a view to its sale for commercial purposes.

He states that he had appointed Mr. Henry E. Roeder, an engineer of New York, his general agent, from whom further particulars regarding the invention and its price could be obtained.

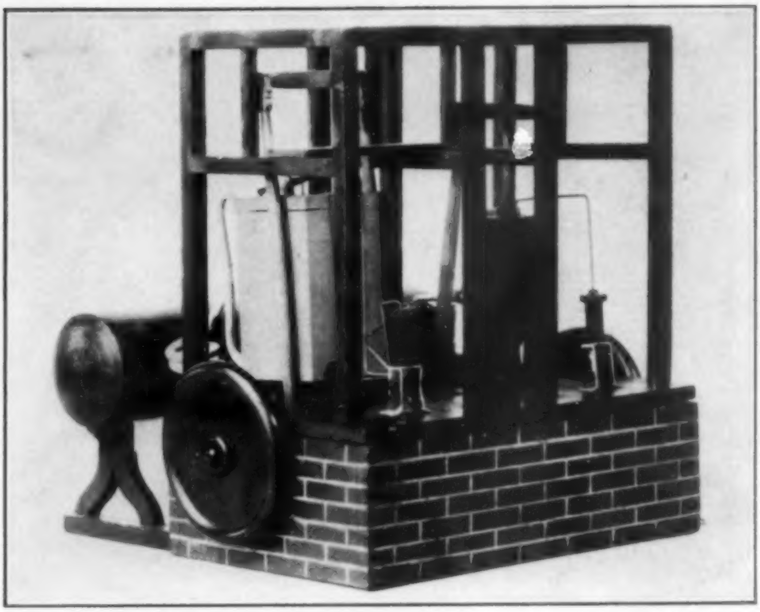


FIG. 2. PHOTOGRAPH OF DR. GORRIE'S MODEL SUBMITTED TO THE U. S. PATENT OFFICE; AS IT EXISTS TO-DAY.

His chief biographer, Mr. George A. Whiteside,[6] states that Dr. Gorrie virtually abandoned his practice in 1844. At this time having exhausted all his means, he went to New Orleans to get capital to build a large machine. He then sold a half interest in the project to a man from Boston, who died shortly thereafter. Unable to interest others in the commercial use of the machine and being penniless he returned to Apalachicola, where he began to brood over his failure to attain commercial success. Remaining almost entirely secluded at his home, he finally became sick, from which he failed to recover, his death occurring on June 18, 1855, after a short illness, at the early age of 52. He was buried, "agreeably to his expressed wishes, upon the beach of the beautiful bay of Apalachicola," in the old beach cemetery. Many years later, in 1893, his remains were disinterred and placed in the present municipal cemetery where they rest to-day.

Dr. Gorrie's scientific papers apparently were not numerous, although a gifted writer. The publications available to-day are to be found in *Silliman's Journal of Sciences and Arts* and the *New Orleans Medical and Surgical Journal*. The paper in *Silliman's Journal* (1850, X, pages 39–49, 214–227) was entitled, "On the Quantity of Heat Evolved from Atmospheric Air by Mechanical Compression." In the first part of this paper he describes the plan and illustrates a machine for compressing air up to 8 atmospheres.

Previous to his paper on the nature of malaria which appeared in the *New Orleans Medical and Surgical Journal*, there appeared another in 1854 in the same journal (1853–4, Vol. 10, pages 584–602, also pages 738–757) entitled "An Inquiry, Analogical and Experimental, into the Different Electrical Conditions of Arterial and Venous Blood." He found that "the normal electrical condition of arterial is one of higher tension than that of venous blood."

[6] *Ice and Refrigeration*, 12: 351, 1897.

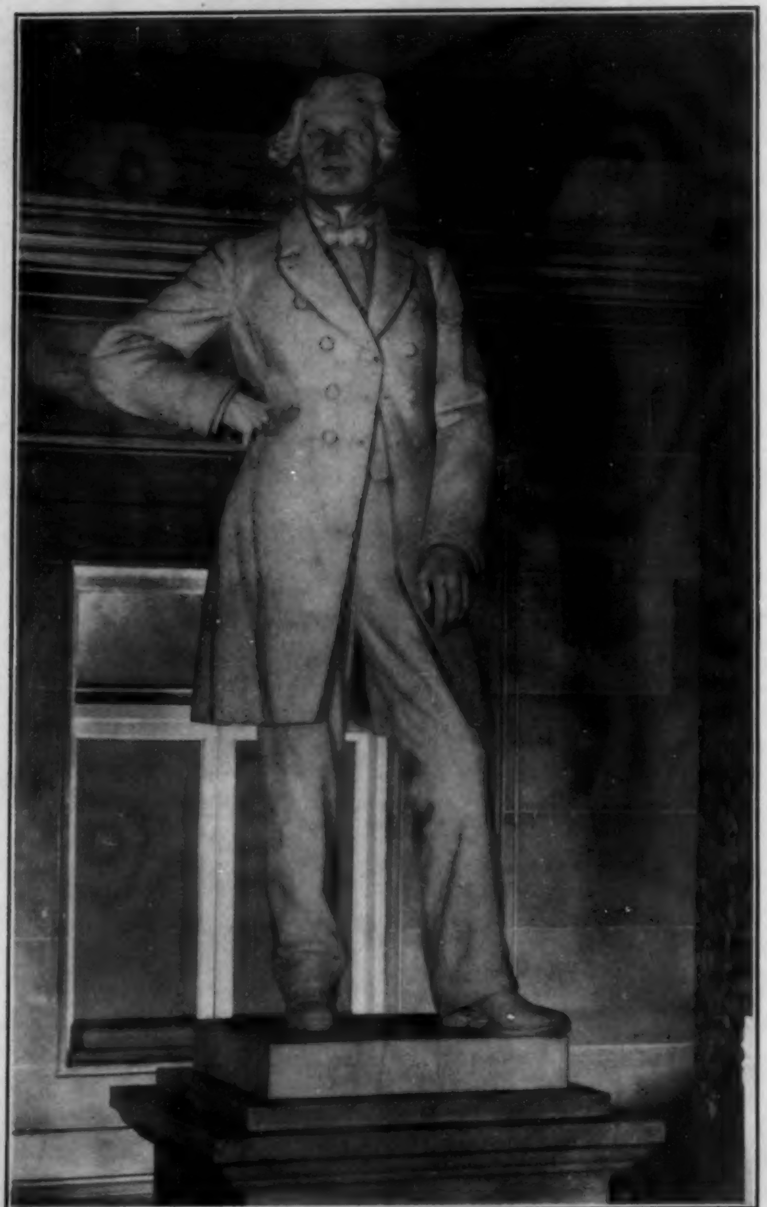


FIG. 3. STATUE OF DR. GORRIE, IN STATUARY HALL OF THE CAPITOL OF THE UNITED STATES.

This paper, as the following quotations will bear testimony, definitely places him in the class with the modern physician of the investigative type.

Physiology is the basis of all medical improvement and in precise proportion as our survey of it becomes more accurate and extended, it is rendered more solid.

The wonderful structure of the animal system will probably never permit us to look upon it as a merely physical apparatus, yet the demands of science require that the evidently magnified principles of vitality should be reduced to their natural spheres, or if truth requires, wholly subverted in favor of those more cognizable by the human understanding. The spirit of the age will not tolerate in the devotee of science a quiet indifference. . . .

From the physician, as emphatically the student of Nature, is expected not only an inquiry into cause, but an investigation of the whole empire of Nature and a determination of the applicability of every species of knowledge to the improvement of his art.

Two public monuments have been erected to his memory: one at Apalachicola, Florida, the other, a statue in Statuary Hall of the Capitol of the United States. The Florida monument, the gift of the Southern Ice Exchange, was unveiled on April 30, 1900. It is a large urn or vase draped with a veil, made of white bronze, which rests on a pedestal whose four paneled sides bear inscriptions of greatest significance in the life of Dr. Gorrie. The statue in Statuary Hall of the Capitol of the United States was placed there through the Act of Congress of July 17, 1864, which allowed "statues of two distinguished citizens from each state who were illustrious for their historic renown"; and the joint resolution of Congress of February 6, 1914.

The statue was unveiled in Statuary Hall on April 10, 1914, and is the work of the sculptor, C. Adrian Pillars, of Jacksonville, Florida, one of the sculptors of the figures for the Columbian Exposition of 1893. Fig. 3 is a reproduction of the statue as it appears in Statuary Hall to-day.[7a]

The state of Florida and its citizenry, medical and lay, have recently established two new memorials to his memory. About a year ago the John Gorrie Memorial Foundation was chartered in Florida to provide hospitalization in Apalachicola and to carry on a nation-wide drive against cancer. More recently, the governor of Florida proclaimed August 11–17 as the "Dr. John Gorrie Ice Memorial Week," which is a plan by which the ice industry gives one day's receipts each year to the Memorial Foundation.

If Dr. Gorrie had not possessed the inventive type of mind, it is extremely doubtful that he would have been thus memorialized, even though it can truly be said that as a physician he was one who was outstanding in the field of scientific medicine.

One of his professional friends and neighbor, the celebrated botanist physician, Dr. Alvan Wentworth Chapman, who settled in Apalachicola in 1847, said to Dr. Asa Gray, the noted botanist of Harvard, when the two passed by Dr. Gorrie's grave, "Gray, there is the grave of the man whom we all recognize as the superior of all of us."[8]

The editor of the *New Orleans Medical and Surgical Journal*, in an obituary notice, likewise regarded Dr. Gorrie as the "distinguished physician and scientist," an "acute thinker" and a "classical writer."[9]

His local lay friends expressed their devotion and regard at his death. It is said that "For two days there was a throng viewing the remains at his home, and the funeral cortege was the largest ever seen in Apalachicola."[10]

[7a] Figures 1 and 2 were kindly furnished by the Smithsonian Institution of Washington, through the courtesy of Mr. Frank Taylor, curator, Division of Engineering; Figure 3, by Mr. David Lynn, architect of the Capitol, Washington, D. C.

[8] *Ice and Refrigeration*, 18: 491, 1900.

[9] *New Orleans Medical and Surgical Journal*, 12: 288, 1855–56.

[10] *Ice and Refrigeration*, 12: 351, 1897.

THE PROGRESS OF SCIENCE

THE FIFTIETH ANNIVERSARY OF ALTERNATING CURRENT

THE March floods solved a problem and staged a demonstration. When plans for celebrating the fiftieth anniversary of the alternating current in America on March 20 were being made by the American Institute of Electrical Engineers some six months ago, it was proposed that the programs in two score cities should not only recount its early history but should feature also its development and its significance in the life of today. The problem was how to impress people by what has become commonplace although it may once have been wonderful. It is sometimes as impossible to realize conditions fifty years ago as it would have been for grandfather to see any sense in the story of a Utopia with flying machines and radio.

TYPE OF TRANSFORMER
USED IN GREAT BARRINGTON DEMONSTRATION FIFTY YEARS AGO.

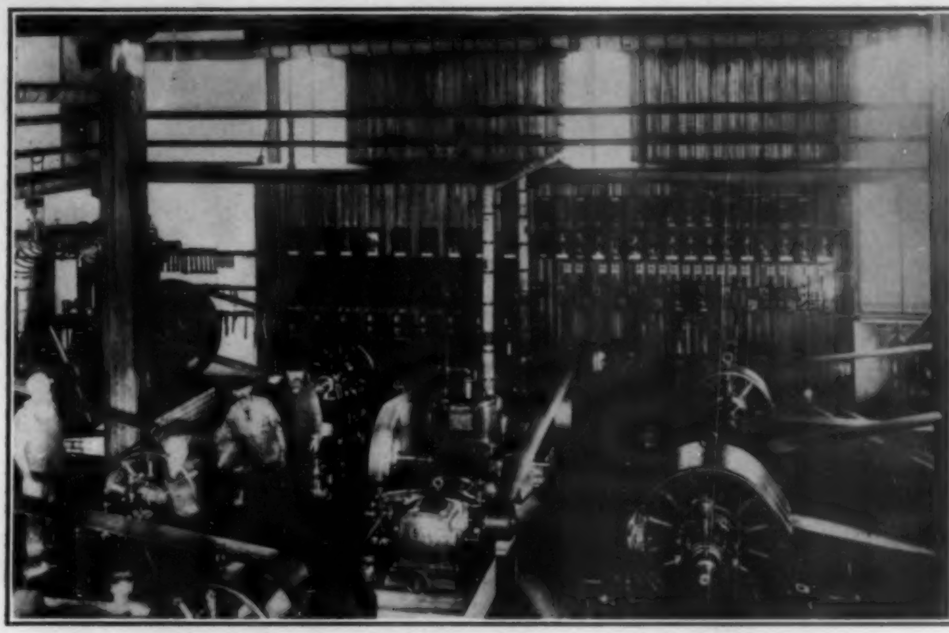
But a few days before the twentieth there came unprecedented floods; in Pittsburgh four feet of water in the hotel banquet room cancelled the local anniversary program. The crowning catastrophe was the submergence of the electric power stations, cutting off electric service. The significance of electric power in our daily life was tragically demonstrated.

On the evening of the eighteenth, I left Pittsburgh (a Venice with dark canal-streets bordered by dark skyscrapers) on a suburban train and presently walked up a dark street to the simple residence where I was staying. Soon I realized the function of electricity in the home by its absence. There are tabulated in the table actual cessations in that ordinary home—light and power, heat and cold, sound and time; fortunately the furnace had no electric regulator or stoker and the range was fed with gas. Outside the house one realized a cessation of street cars, street lights, newspaper presses, gasolene pumps and building elevators. The emergencies in home life become calamities in hospitals, public service, commercial buildings and industries.

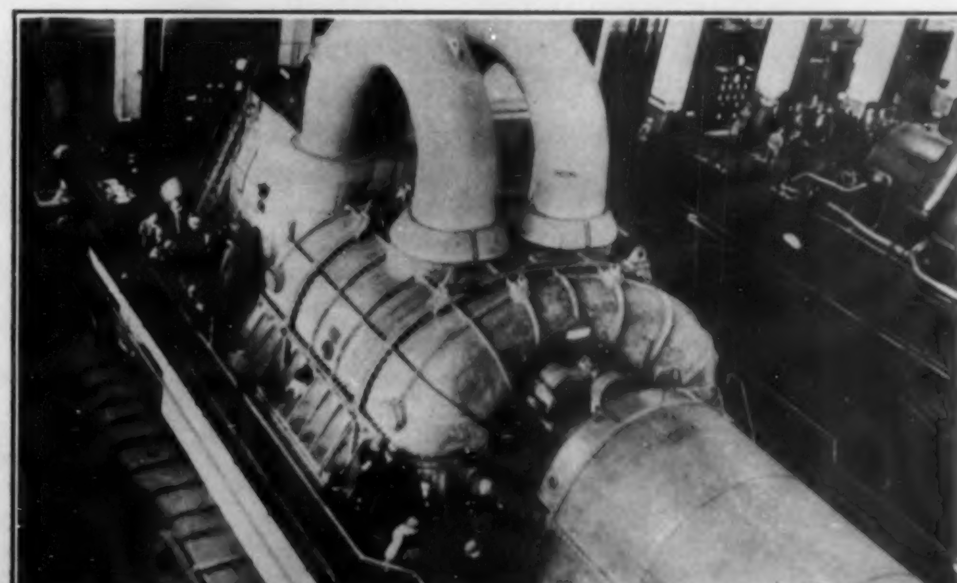
And thus we realize that we are living in the age of electric power. What is it? Whence came it? Power and electricity—the two in a sort of combination. Power—other than muscle power—came into common use with Watt's steam-engine, invented about the time of the

A SUBURBAN HOME LOSES ITS ELECTRIC CURRENT

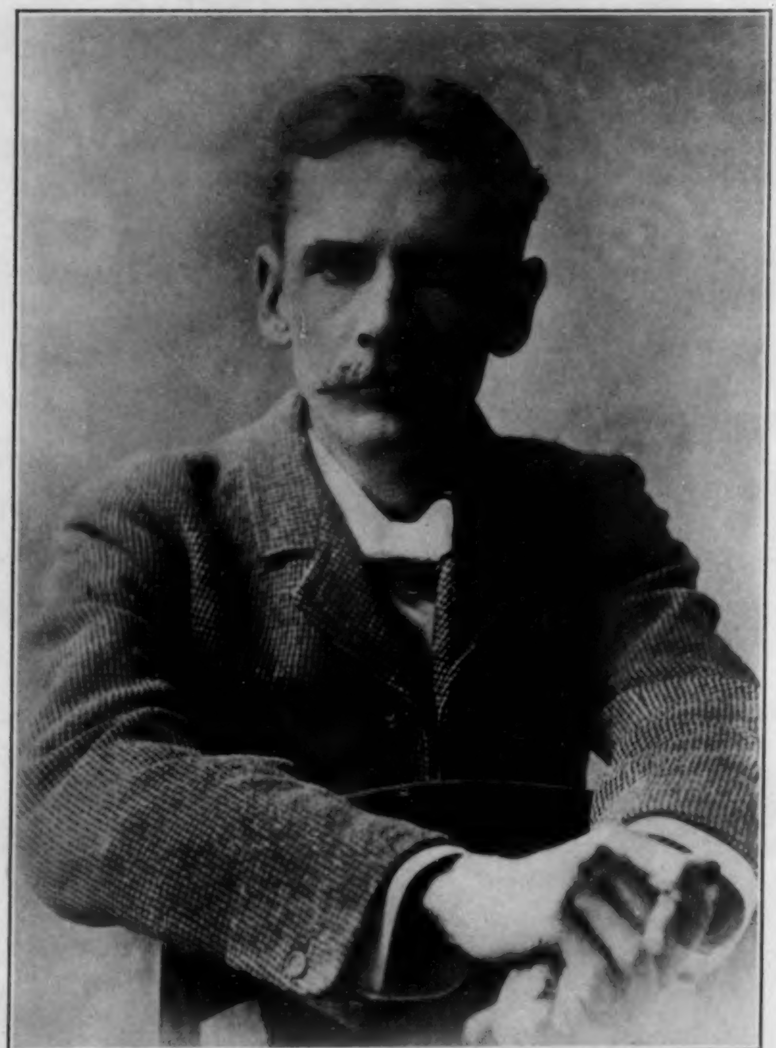
What stopped	Old-time methods
Electric lights	Candles
" sweeper	Broom
" washer	Wash-board
" toaster	Stove
" iron	Flat-iron, stove
" pad	Hot brick
" refrigerator	Ice
" door bell	Knocker
" radio	———
" clock	Grandfather's clock
Telephone (no current)	———
Water (no electric pumping)	Well and cistern



AN EARLY ALTERNATING CURRENT CENTRAL STATION
WITH SEVERAL BELT-DRIVEN ALTERNATORS. TOTAL CAPACITY, ABOUT 200 K. W.



TURBINE GENERATOR IN PHILADELPHIA.
LARGEST OF ITS KIND (165 K. W.). BUILT BY WESTINGHOUSE.



WILLIAM STANLEY

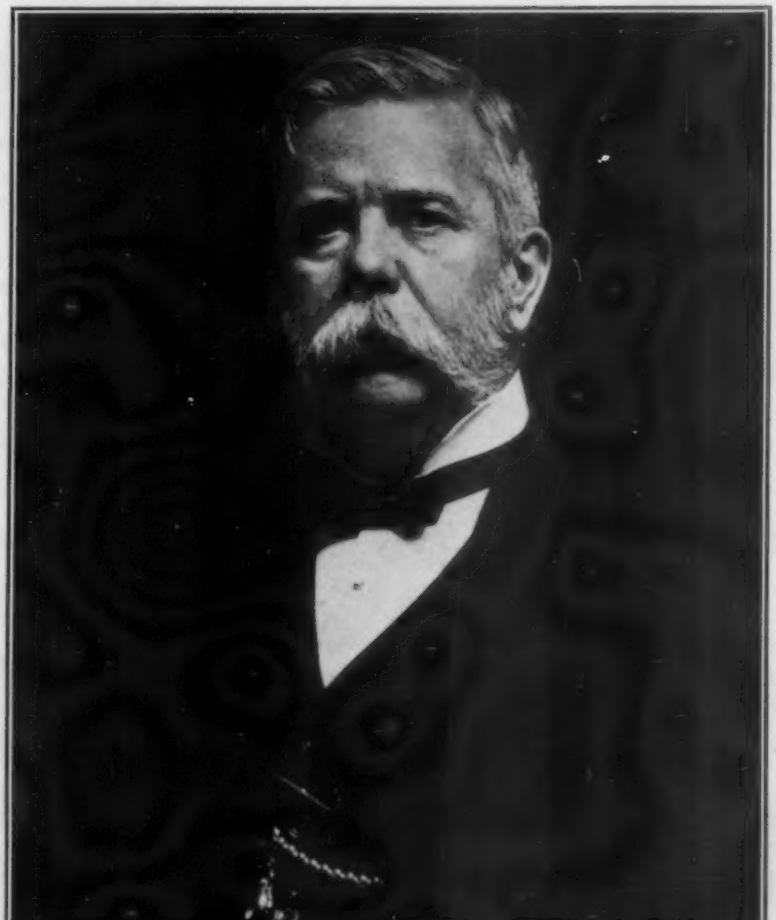
ELECTRICAL ENGINEER WHOSE PIONEER PLANT AT GREAT BARRINGTON, MASS., INAUGURATED THE ALTERNATING CURRENT SYSTEM IN THE UNITED STATES.

Declaration of Independence. After a century it was running steamboats and railway trains and factory machinery through shafting and belts. Electricity is thousands of years old—the frictional kind that Benjamin Franklin said gave no promise of being of use to mankind. Then came batteries in 1800, followed by the telegraph, electro plating and the telephone; also scientific studies which through Faraday and his followers eventuated in the dynamo. Expensive battery current has been replaced by cheap dynamo current as the driving power is steam or falling water. Thus mechanical power now becomes electric power which can be transmitted far beyond the range of belts and shafts and can be converted into motor power or light or heat or used for chemical pur-

poses. Thus electricity amplifies the usefulness of power.

At the Centennial in 1876 Professor Elihu Thomson got a thrill which shaped his career from "a dynamo which ran one arc lamp." Within the next half dozen years there came arc lighting for streets, and incandescent lighting for interiors—thanks to Edison's lamp and system. From his Pearl Street (New York City) station in 1882 came electric energy as a commercial commodity. But a half mile or so was the limit, beyond which the cost of conductors became excessive.

George Westinghouse, having established the air brake, sought new activities. The electrical field was attractive. He secured William Stanley, electrical inventor, who developed direct current appliances for incandescent lighting which Westinghouse manufactured. But the few thousand feet which limited the commercial radius made the prospect uninviting. He learned of a foreign system employing alternating current with high pressure for transmission over long distances and a "secondary generator" (transformer) for reducing the pressure for use. This was analogous to his own



GEORGE WESTINGHOUSE,
SPONSOR OF THE ALTERNATING CURRENT.

system for transmitting natural gas at high pressure with reducing valves for adapting it for service. He at once acquired rights and apparatus; Stanley as electrical expert proposed changes based on electrical features—counter electromotive force, magnetic circuit, windings and circuit connections. Westinghouse, mechanical expert, proposed reconstruction so that the coils could be wound in a lathe. A new company was formed and arrangements made for a demonstration plant to be built by Stanley at Great Barrington. Generators and transformers from the Pittsburgh factory were supplemented by transformers made at Great Barrington. The plant began service on March 20, 1886, supplying a score of houses and stores with incandescent lamps for three months. Its success was followed by commercial plants, beginning at Buffalo on Thanksgiving Day, 1886.

The service was incandescent lighting and its merit was its suitability for long distance transmission.

Next came the Tesla polyphase system. Its mechanical analogue is a two-crank or a three-crank instead of a single-crank ("single phase") engine. This system operates induction and synchronous motors and is adapted for supplying all electric services from one source. Formerly arc lighting, incandescent lighting and street railways required different kinds of generators and independent circuits. Furthermore, the largest direct circuit generating units are structurally limited to five or ten thousand kilowatts, while alternators are made for twenty times that output. Thus the new alternating system is suited to large units, to transmission, to conversion into various forms suited to the universal service which it now renders. It was demonstrated at the Chicago World's Fair in 1893 and commercially inaugurated at Niagara in 1895.

The simple beginnings of fifty years ago were followed by scientific research, engineering development of apparatus, manufacturing facilities, power stations and transmission systems, motors and appliances—all these providing the physical equipment. These have involved the creation of new industries with new fields of employment. Remote water powers have become national assets involving new questions of governmental policy and constitutional interpretation. The new uses of power ramify our industrial, commercial and social life. Herbert Hoover said "Electricity is the greatest tool that ever came into the hands of man"; and we celebrate the beginning of the transformer which contributed to make it so.

CHARLES F. SCOTT

THE NATURAL HISTORY MUSEUM AT PHILADELPHIA

A PROGRAM which will make the Academy of Natural Sciences of Philadelphia an active part of that city's educational system was announced by Effingham B. Morris, president of this institution, the oldest of its kind in America, at the recent opening of the new East African water-hole habitat group in African Hall in the academy's museum. Dr. James Bryant Conant, president of Harvard University, and Dr. William Berryman Scott, emeritus professor of geology at Princeton University, who spoke at the large gathering of academy members and guests, urged the carrying out of this program, which embodies extensive additions to and rearrangement of present exhibits in the academy's Free Natural History Museum; active cooperation with public and private schools in and near Philadelphia in the study of natural history subjects, and the reestablishment of the academy's department of paleontology. The latter will continue the study of the history of life through its priceless collections of fossil remains of past geological periods and thus accomplish the first step in meeting the

THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA

growing demands of nearby centers of higher education for cooperation in all fields of scientific research.

From its founding in 1812 and until 1929 the academy continued to grow in scientific importance, but the public was not kept in touch with its development. It could not be expected that such a man as Joseph Leidy, one of the greatest naturalists who ever lived and father of vertebrate paleontology in America, should take the time from his life's work to build popular exhibits for the edification of a public uninformed in the fundamentals of his subject.

He served the public, but in a larger sense. He built up his branch of the natural sciences so that to-day all the great oil companies of the world owe him a debt of gratitude as well as the coal consumers of every household. For it is often owing to the efforts of the research scientist who labored in a field where at first there seemed no "practical" advantage that mankind has ultimately benefitted from science.

In 1929 the picture began to change. New trustees, a new president, and a new managing director found a new interest and understanding on the part of the public. They knew that the life of the institution lay with its men, but they also found that the average American was demanding an increasing service from its scientific institutions—that the public, as well as the scientist, was turning more and more to the academy for what it could give. Steps were taken accordingly, and in the last six years the visitor to the academy has found an attendance increased seven-fold: classes of school children viewing the exhibits; new specimens brought back from more than 130 scientific expeditions to the remote places of the six continents; a museum changed from what formerly must have seemed an old curio shop to one with more meaning; notable life groups of animals in their native habitats reproduced in detail, accurate to the smallest blade of grass.

Recognizing museum exhibits as the open door to an awakening of interest in the fascinations of natural history, the trustees of the academy have decided that a study should be made to show just how its free museum should be arranged and what it should do. Despite great advances, the possibilities in museum planning are just beginning to be realized. It is the determination of the trustees that the academy shall contribute to the advancement of this essential service to the public.

JOSEPH LEIDY
—A RARE PHOTOGRAPH MADE ABOUT 1858, ALSO SHOWING ONE OF THE BONES OF THE HADROSAURUS FOULKII, THE SKELETON OF WHICH WAS UNEARTHED IN THAT YEAR NEAR HADDONFIELD, N. J. LEIDY, WHO THEN WAS DOING BRILLIANT WORK AT THE ACADEMY OF NATURAL SCIENCES, OF WHICH HE LATER BECAME PRESIDENT, DESCRIBED THIS FOSSIL LIZARD, WHICH WAS THE FIRST DINOSAUR TO BE FOUND IN THE EASTERN UNITED STATES. A RESTORATION MADE BY B. WATERHOUSE HAWKINS, OF LONDON, STILL IS ON EXHIBIT IN THE ACADEMY'S FREE NATURAL HISTORY MUSEUM.

Closely related to museum planning, but, nevertheless, a field of its own, is the development of an active program of education in cooperation with the Philadelphia public and with grade and private schools. The start already made, which last year brought more than 30,000 school children to the academy, some coming from such relatively distant points as Atlantic City and Reading, and 150,000 adults, has only given evidence of the need. The merits of arousing the child's interest in science are recognized to-day by ever-increasing numbers. The importance of the natural science particularly can not be overstated, since an interest in natural history takes the child out of doors and brings a healthy and wholesome influence into his or her life.

In that great branch of the natural sciences where the study of the earth and the study of the life upon it meet, that of the fossil remains of ancient life as revealed in the rocks, or technically the division of geology known as paleontology, the Academy of Natural Sciences has a proud tradition. In the work of men like Leidy and Cope, two of the academy's greatest scientists, there is a unique heritage. It is the determination of the trustees to reestablish this department, to bring to the academy's staff an able scientist, and to put in order the priceless collections which are now unavailable for study.

Increasing recognition is to-day being given to the vital need for closer cooperation of the college and university with the research center. There can be no questioning the fact that graduate students and professors alike can benefit greatly from a closer relationship with institutions like the academy which have great collections and skilled research scientists. The academy has the opportunity of building, without fear of duplication—indeed, to fill a great gap—a department of paleontology designed particularly with a view to meeting the demand for cooperating with nearby institutions of higher education.

These are the first three steps. Because they have been undertaken first does not mean that the other activities of the academy will be neglected. It is admitted that there are pressing demands upon the services of the library, the department of publications, and that there is a definite need for more staff and equipment for all phases of the institution's scientific work. These needs will be studied also.

L. M. H.

ISLE ROYALE AS A NATIONAL PARK

Announcement that Isle Royale, island wilderness far out in Lake Superior, may soon become a national park is of especial interest to the naturalist, botanist and ethnologist. This hitherto secluded area, up to now absolutely unspoiled, has been in the public eye of late because of rumors that the virgin timber with which the island is covered was about to be logged. Michigan, Wisconsin and Minnesota conservationists have organized the Isle Royale National Park Association, with offices in Escanaba, Michigan, to further by all means in their power the early consummation of plans to convert the entire area into a national park, which will become at the same time a primeval forest preserve and a sanctuary for the largest herd of moose on the continent.

Isle Royale[1] lies about forty-five miles north and west of Keweenaw Point, which is the northernmost locality on the Michigan mainland. The island occupies a northeast and southwest position fourteen miles from the nearest Canadian shore. It is forty-four miles long and from three to nine miles wide, with an approximate area of 205 square miles, of which twelve square miles are occupied by more than twenty-five lakes. Hundreds of rocky islets surround the main islands, forming an archipelago with a total length of fifty-seven miles. The island is the largest in the Great Lakes owned by the United States.

The geological formation of Isle Royale consists of a series of upturned lava flows, striking southwest and with a dip to the southeast. The strata of lava disappear with the lake and make their reappearance on the south side of the latter, where they emerge to form Keweenaw Point. The truncated ends of these ancient lava flows form long ridges ranging from one hundred to five hundred feet in height.

Glacial action has removed the softer strata, but enough of the latter have remained to provide sustenance for at least twenty-one species of trees, of which thirteen are deciduous and the balance evergreens. As a whole the

[1] The photographs have been loaned to the author by the Superior Art Company of Houghton, Michigan.

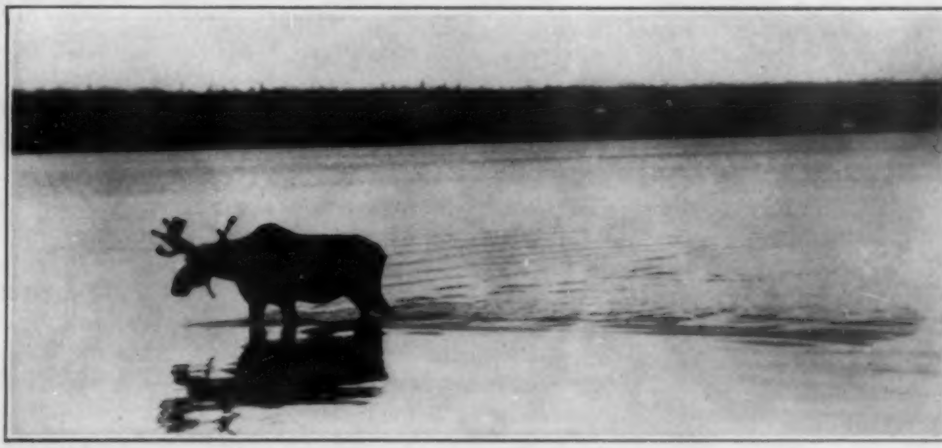
ROCKS OFF THE MAIN ISLAND

Isle Royale and its more than 1,000 islets were hurled ages ago from the mouth of some long-extinct volcano. The fantastic lava formations extend over 50 miles, and are covered for much of the distance by primeval forests untouched by ax or fire.

MOONLIGHT AT ISLE ROYALE

island is heavily timbered with trees that have never been cut and are little harmed by the ravages of fire. The dominant species are the balsam fir, the white or canoe birch and the black or cherry birch, as well as the hard maples and some oaks.

The birds on the island are those of the mainland on both sides of the lake, including many of a sub-arctic type. The animals include most of the species of sub-arctic Canada and northern Michigan, including moose, woodland caribou, the Canadian lynx and the timber wolf. Isle Royale is said to be the only home of the woodland caribou in the United States.



MOOSE ON ISLE ROYALE

The moose herd is probably the largest single herd in North America. The increase of the moose on the island is of comparatively recent occurrence. Twenty years ago they were scarcely to be found there. At present there are probably 450 to 500 moose on Isle Royale, and a limited number were removed recently by the Michigan Department of Conservation to the northern mainland counties because of a growing food shortage. The transference of animals will probably continue, and meanwhile the food situation is being carefully studied by department mammalogists.

While the moose are one of the largest animals in the western hemisphere, they are quite harmless, and individuals occasionally wander into the hotel premises on the island. Because of its exceptionally pure and dustless air the locality has been for years a haven for people of the central west who are suffering from hay fever, and a large part of the summer hotel patronage is composed of hay fever and asthma patients. The four hotels operate from June 25 to the close of the hay fever season, and their combined capacity is about four hundred.

The north and south shores of the island are liberally dotted with copper mining pits made by some prehistoric race whose identity remains a mystery. The characteristically pure native copper of Isle Royale is found in many burial and other mounds in the southern states and Mexico, yet no copper was in use by the Indian tribes when America was discovered. Archeologists and ethnologists have made numerous expeditions to the island in endeavors to trace the unknown miners, and other excursions of the kind are in prospect for this year. It has been found that trees over four hundred years old are growing in some of the pits, but no one knows how much older the latter may be. The excavations represent a

volume of toil comparable to that exercised in the building of the great pyramids of Egypt, and the quantity of copper recovered must have totaled hundreds of tons.

Couple these factors with the undeniably good fishing on and around the island, the average summer temperature of 64 degrees and the fact that no roads other than moose trails exist from one end of the terrain to the other, and it will be recognized that Isle Royale as a national park will be unique and very different from any other park in the national chain. The island lies within a day's run or a night's journey of many millions of people, and its accessibility is now beyond question.

Harvesting operations of Isle Royale timber must be prevented at all hazards. Logging there will not only scar a landscape of aboriginal loveliness but create a fire hazard which may do untold damage requiring centuries to repair, and destroy the home of the moose that are now so great an attraction. The move, therefore, to keep Isle Royale precisely as it is is in line with the soundest ideals of practical conservation—ideals which are touching a responsive chord in the soul of America. The proponents of the park plan for Isle Royale have been heartened indeed by the stirring response to their appeal for cooperation.

W. D.

EXPERIMENTAL BIOLOGY AT THE WASHINGTON MEETINGS

THE Federation of American Societies for Experimental Biology, which convened in Washington for four days at the end of March, is composed of four societies having a common interest. They are the American Physiological Society, the American Society of Biological Chemists, Inc., the American Society for Pharmacology and the American Society for Experimental Pathology. A large proportion of the members of the American Institute of Nutrition are also members of one or more of the societies in the federation and it met with the larger group.

The extent and interest in experimental work in the past year is indicated by the fact that in four days approximately 1,700 scientists listened to one or more of 470 papers and saw forty demonstrations; ninety-three papers were read by title. Eleven formal sessions were held simultaneously. In addition there were countless conversations outside the meeting rooms, conversations that are often the most stimulating part of a convention. The following annotations indicate some of the results reported at the meetings:

As a result of relief measures, the depression did not adversely affect the nutritional status of the average individual in the United States. In fact, the poor were often better fed than formerly. The greatest hardship fell on those who changed from a relatively comfortable to a poor economic state. The ordinary heating of protein, such as meat or milk, does not affect its nutritive value, provided the digestibility of the food is not lowered. Growing children show a variable and often a step-wise retention of protein. Experiments indicate that care should be taken to see that the diets of children contain adequate amounts of Vitamin A or carotene, and the Vitamin B complex. Vitamin G, present in many foods, especially meat, milk, eggs, wheat germ and many vegetables, is a factor, along with Vitamin A, in good eyesight. Cataracts often accompany retarded growth when Vitamin G is lacking in the body. Flavins, pigments in eggs, liver and milk and other foods affect growth. They stimulate the appetite. There are at least two antirachitic vitamins (Vitamins D). Both vitamins are obtained by irradiation

with ultra-violet light. The one in fish oils is most efficient with children. The other, obtained from cholesterol, is more effective with poultry.

Certain amino acids, the fundamental constituents of protein, can not be made by animals, and must be obtained from food. The search for a mixture of amino acids that will support life led to the discovery, reported last year, of a new amino acid hitherto unrecognized as essential. It was l-α-amino-d-β-hydroxy-n-butyric acid, and has now been named threonine. A sulfur containing amino acid, methionine, has been found to be essential. Whether or not methionine can completely replace cystine, formerly held to be essential, remains to be shown. The essential amino acids at present known are lysine, tryptophan, histidine, phenylalanine, valine, leucine isoleucine, methionine, hydroxy-amino butyric acid, (cystine ?).

The early water soluble Vitamin B was once supposed to be a single substance. Now it is sometimes called "Vitamin B Complex." Six Vitamins B have been suggested, plus two other factors, one known as flavin, and the other as the pellagra preventive factor for man. Some of these factors may be duplications. Other members or manifestations of the B complex were described at the meetings, such as a factor which prevents characteristic lesions in chicken gizzards, another factor which prevents severe skin diseases in rats and chickens, also necessary for growth, and a new vitamin H.

Hormones and their effects were discussed at nearly every session of the meeting. A new hormone, lipociac hormone, was described, which apparently controls the utilization of fat in the body. Evidence of a new hormone in the adrenal gland, in addition to adrenaline and cortin, was presented. This hormone appears to control the decrease in size of the thymus gland. This gland has a relation to early growth and development. It normally decreases in size during childhood. Evidence that the thymus gland influences the growth and development of young was presented. Injections of the thymus gland were injected into successive generations of male and female rats. Up to the twelfth generation, the young of each succeeding generation showed a greater rate of growth and maturity than the preceding generation. Extracts of the pineal gland, in the brain, showed the opposite effect. There was an accruing retardation in the rate of growth, accompanied by an accruing development of the young. The presence of a fourth hormone in the adrenal gland, cortipressin, was suggested. This hormone appears to be effective in raising the blood pressure.

The specific effects of hormones on particular processes are steps in understanding body function. Life is not a series of isolated activities, but the interaction of all processes. The pituitary gland in the skull appears to be a regulating center of hormone activity. The pituitary was shown to play a part in keeping a balance between the liberation of sugar, probably in the liver, and the secretion of insulin needed in the utilization of sugar. The pituitary was also shown to influence the production of the hormone of the adrenals, mentioned above, affecting the involution of the thymus. The activity of the pituitary gland is affected by disturbances in the body. One such evidence was given in the demonstration that when the nerve supply between a small nerve center, the supra-optic center, in the brain to the pituitary gland is severed, an excessive loss of water occurs through the kidneys. The ultimate effect is believed to be due to the action of a pituitary hormone on the kidneys.

Study of the brain and nervous system has shown that consciousness or unconsciousness may depend upon an electrical state of the brain. When the electrical potential of the cerebral cortex is

higher than that of the rest of the nervous system, the animal is "conscious." When it is lower, "unconsciousness" results. The suggestion was made that electrical response is basic to hearing. The transmission of sound begins with certain fine, hair-capped cells in the inner ear. Loss of hearing is accompanied by the total or partial destruction of these cells. There is a "safety factor" in hearing. Both sides of the brain can detect impulses from the sound-receiving organ in either ear.

The depth of sleep varies during the night. Every one moves more or less when sleeping. After a movement the depth of sleep gradually increases to gradually decrease again as the time for another movement approaches. Sleep is deeper the longer the time between movements. The knee jerk may be a useful test of "physical fitness." An increase in physical or mental work, with accompanying fatigue, required a heavier blow on the knee to cause a response than after rest. The lightest blow was required upon arising in the morning. Recovery from fatigue was more rapid in the "physically fit." The time required for a human stomach to empty after a meal increased with the altitude. Fifty per cent. more time is required to empty a stomach at Pike's Peak than at sea level. The beating of the hearts of dogs could be restored five to seven minutes after the heart had entered the state of fibrillation, which precedes complete stopping, through the application of an alternating electrical current. If the heart is massaged just before applying the shock, the expectancy for revival could be tripled or quadrupled. When the fore legs of salamanders were interchanged by a surgical operation, the legs continued to move in the direction in which they were accustomed, that is, backward when the animal was trying to go forward.

Alcohol was shown to increase the deposition of fat in the liver, even on a diet which produces fatty livers. That the toxemia of pregnancy may be hereditary was indicated by experiments on rabbits. The disease studied is a disorder of carbohydrate and fat metabolism. The association with pregnancy is due to the metabolic activity of the mother, rather than to the specific effect of the developing young. Removal of the ovaries from female mice resulted in marked decrease in the incidence of cancer of the mammary gland to which that particular strain was susceptible. If the ovaries were removed early in life, cancer did not develop. On the other hand, if the removal was delayed until the mice were eight or nine months old, removal of the ovaries was ineffective. Large doses of the female hormone from the ovaries into male or female mice increased the incidence of cancer.

A new internal antiseptic, phenthiazine, that shows great promise if properly used, has been found as a result of studies on the toxicity of this substance in connection with investigations of insecticides for fruits and vegetables. Caffein, the nerve-stimulating alkaloid of the coffee bean, decreases reaction time (increases speed) and the accuracy of a simple hand movement test. Taken in the form of coffee, however, its effect is only about half as great. Deuterium, or heavy hydrogen, given in the form of heavy water, was employed to tag water used in the synthesis of fatty acids in the body. The data indicated that there is a continual synthesis and utilization of fats in the body.

Paul E. Howe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